

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2002-175123
 (43)Date of publication of application : 21.06.2002

(51)Int.CI. G05D 23/22
 H01L 21/22
 H01L 21/324

(21)Application number : 2001-272218 (71)Applicant : HITACHI KOKUSAI ELECTRIC INC
 (22)Date of filing : 07.09.2001 (72)Inventor : TANAKA KAZUO
 UENO MASAAKI
 NAKANO MINORU
 YAMAGUCHI HIDETO

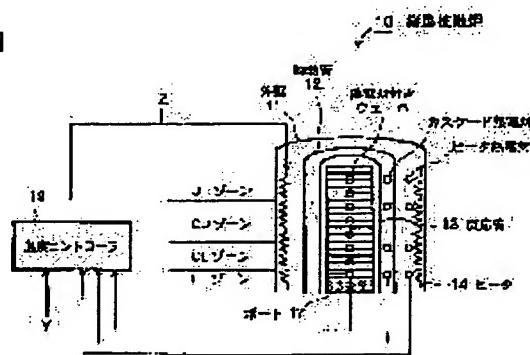
(30)Priority
 Priority number : 2000298858 Priority date : 29.09.2000 Priority country : JP

(54) TEMPERATURE CONTROL METHOD, HEAT TREATMENT DEVICE AND METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a temperature control method making it possible to perform accurate heat equalizing adjustments with little error in a short time over an entire wafer area to be heat treated at a desired temperature, even without a skilled operator, and also enabling automation using a computer system.

SOLUTION: The temperature control method is for controlling a heating device having at least two heating zones, so that the temperature detected at the wafer position attains the desired temperature. Temperatures are detected in positions more than the number of the heating zones and in at least one wafer position in each heating zone, and the heating device is controlled so that the desired temperature is within the range between the maximum and minimum values of the plurality of detected temperatures.



LEGAL STATUS

[Date of request for examination] 29.03.2005

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision
of rejection]

[Date of requesting appeal against examiner's
decision of rejection]

[Date of extinction of right]

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【特許請求の範囲】

【請求項1】 所定位置での検出温度をその目標温度とするよう、少なくとも2つの加熱ゾーンを有する加熱装置を制御する温度制御方法であって、前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおいて少なくとも一つの所定位置での温度を検出し、検出された複数の所定位置における検出温度の最大値と最小値の間に前記目標温度が含まれるように前記加熱装置を制御することを特徴とする温度制御方法。

【請求項2】 請求項1に記載の温度制御方法において、

各ゾーンに対応する第1の所定位置に第1の温度検出器を備え、前記第1の温度検出器による検出温度を第1の目標温度とするように前記加熱装置を制御する温度制御方法に用いられ、

第1の所定位置よりも被処理物に近い第2の所定位置に第2の温度検出器を備え、前記第1の温度検出器における前記第1の目標温度を変化させた場合に、前記第2の温度検出器の検出温度が変化する度合いを示す係数の行列である干渉行列M、及び前記第2の温度検出器における第2の目標温度と前記第2の温度検出器による検出温度との差P₀を取得し、

これら干渉行列Mと誤差P₀とに基づいて、前記第1の目標温度を補正することを特徴とする温度制御方法。

【請求項3】 請求項2に記載の温度制御方法において、

前記補正された第1の目標温度を用いて温度制御を行うことで、新たな誤差P_{0'}を求め、この誤差P_{0'}と前記干渉行列Mを用いて、前記補正された前記第1の目標温度をさらに補正することを特徴とする温度制御方法。

【請求項4】 処理室と、

少なくとも1つの加熱ゾーンを有し、前記処理室内に設けられた被処理物を加熱する加熱装置と、

前記加熱装置による加熱温度を第1の所定位置にて検出するため、各ゾーンに少なくとも1つ設けた第1の温度検出器とを備え、

前記第1の温度検出器により検出された第1の検出温度と、該第1の検出温度についての第1の目標温度に基づいて前記加熱装置を制御する温度制御方法において、前記加熱ゾーンの数よりも多く、第1の所定位置よりも前記被処理物に近い第2の所定位置において前記加熱装置による加熱温度を検出する複数の第2の温度検出器を備え、

前記第2の温度検出器により検出される第2の検出温度と該第2の検出温度についての第2の目標温度とを比較して前記第1の目標温度の補正值を取得し、前記補正值により前記第1の目標温度を補正して温度制御を行うことを特徴とする温度制御方法。

【請求項5】 請求項4に記載の温度制御方法において、

前記補正值の取得は、実際に被処理基板を処理する実プロセス前に行われることを特徴とする温度制御方法。

【請求項6】 処理室と、

所定位置での検出温度をその目標温度とするよう温度制御される、少なくとも2つの加熱ゾーンを有する加熱装置と、

前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおける少なくとも1つの所定位置における温度を検出する複数の温度検出器と、

前記複数の温度検出器による複数の検出温度の最大値と最小値の間に前記目標温度が含まれるように、前記加熱装置を制御する制御装置とを備えてなる熱処理装置。

【請求項7】 所定位置での検出温度をその目標温度とするよう、少なくとも2つの加熱ゾーンを有する加熱装置を制御し、被処理基板に加熱処理を施す半導体装置の製造方法であって、前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおける少なくとも1つの所定位置における温度を検出し、検出された複数の所定位置における検出温度の最大値と最小値との間に前記目標温度が含まれるように前記加熱装置を制御することを特徴とする半導体装置の製造方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】この発明は、半導体製造装置等における温度制御方法、熱処理装置、及び半導体装置の製造方法に関し、特に、被処理体を熱処理するためには、熱処理装置を複数の加熱ゾーンに分割し、該複数の加熱ゾーンに関して、実際に目標温度を設定して温度制御を行い、前記複数の加熱ゾーンよりも多数の被処理体領域における検出温度により、前記目標温度を補正するようにした温度制御方法、熱処理装置及び半導体装置の製造方法に関する。

【0002】

【従来の技術】従来の熱処理装置において、例えば、半導体ウェーハ（基板）を被処理体として熱処理し、成膜等を行う場合、その処理成果物である成膜等の種別およびその製造過程に対応した様々な処理温度が要求される。したがって、熱処理を行うときの被処理体の温度は、この処理温度に可能な限り一致するような方法（均熱調整方法）で温度制御される。図6は、このような熱処理装置の中の典型的な一つである縦型拡散炉の構造を示す図である。図6に示した縦型拡散炉は、外壁111に覆われた均熱管112および反応管113と、反応管113の中を加熱するためのヒータ114と、ヒータ114の温度を検出するヒータ熱電対115と、均熱管112と反応管113との間の温度を検出するカスケード熱電対116と、熱処理するためのウェーハを搭載したポート117と、ヒータ熱電対115およびカスケード熱電対116が検出する検出温度および指示される目標温度Yに基づき、ヒータ114への操作量Z（電力値）

を制御する温度コントローラ119とから構成されている。

【0003】ヒータ114は、炉内温度（反応管113の温度）をより高精度に制御するために複数の加熱ゾーンに分割されており、例えば、図6のように、4つの加熱ゾーンへの分割の場合には、上部から順にU, C U, CL, Lゾーンと呼ばれる（以降、これらの名称を使用する）、それぞれの加熱ゾーンに対応して、ヒータ熱電対115とカスケード熱電対116とが設置されている。温度コントローラ119は、カスケード熱電対116の検出温度を目標温度Yと一致するように、ヒータ熱電対115の温度を検出しながら、ヒータ114への操作量Zを予め与えられたアルゴリズム（PID演算等）に従って算出し、ヒータ114への電力値を調整している。

【0004】このように、従来は、カスケード熱電対116での検出温度を、ウェーハ処理の目標温度に一致するように温度制御を行っていたが、実際に熱処理を行うウェーハの位置での温度と、それに対応するカスケード熱電対の検出温度との間には、少なからず誤差があり、この誤差が熱処理の品質を低下させる要因となることがある。このため、ウェーハにより近い領域の温度、またはウェーハそのものの温度をウェーハ処理の目標温度になるように制御し、熱処理の品質を向上させることが必要である。そのためには、ウェーハにより近い領域の温度、またはウェーハそのものの温度を検出する手段が必要となる。検出手段としては、反応管の中に熱電対を挿入し、ウェーハ近傍の温度を測定する方法や、数学モデルを使用してウェーハ温度を推定する方法等各種のものがあるが、ここではそれらの1例として、熱電対を直接的にウェーハに装着した温度測定用ウェーハ（熱電対付きウェーハ）を使用する方法について説明する。

【0005】図7は上述の熱電対付きウェーハを使用した例を示す。この場合、熱電対付きウェーハ118は、4つの加熱ゾーンであるU, C U, CL, Lゾーンのそれぞれに対応して配置されている。また、ヒータ熱電対115およびカスケード熱電対116もこれらのU, C U, CL, Lゾーンのそれぞれに対応する位置に設置されている。熱電対付きウェーハ118で検出された温度は、ヒータ熱電対115およびカスケード熱電対116と同様に、温度コントローラ119に取り込まれる。ちなみに、熱電対付きウェーハにおいて、熱電対を装着する場所や数は、使用方法によって異なる場合があるが、ここで述べる例における熱電対付きウェーハ118は、ウェーハの中央に熱電対を1個だけ装着しているものとする。

【0006】図7のような構成で、カスケード熱電対116の検出温度をウェーハ処理の目標温度に一致するように温度制御を行った場合の、カスケード熱電対116と熱電対付きウェーハ118の検出温度の関係の1例を

図9に示す。この場合、カスケード熱電対116の検出温度（○）は、目標温度に一致するが、熱電対付きウェーハ118の検出温度（△）は、目標温度との間に誤差が生じている。また、誤差の大小等も加熱ゾーン毎に異なっているため、熱処理の品質を低下させる要因となる。この場合、熱電対付きウェーハ118の検出温度とカスケード熱電対116に対する目標温度との間の誤差を、カスケード熱電対の目標温度に対する補正值として使用する方法がある。例えば、図9において、Uゾーンの熱電対付きウェーハの検出温度が、目標温度に対して5℃低い場合には、この5℃を、Uゾーンのカスケード熱電対に対する目標温度に補正值として加える。

【0007】上述の補正により、Uゾーンのカスケード熱電対116の検出温度は、本来の目標温度よりも5℃高くなるが、Uゾーンの熱電対付きウェーハの検出温度を、本来の目標温度に一致させることができる。同様に、全ての加熱ゾーンに対して、補正を行った場合のカスケード熱電対と熱電対付きウェーハの検出温度の関係の1例を図10に示す。この場合、カスケード熱電対116の検出温度（○）は、本来の目標温度に一致しなくなつたが、熱電対付きウェーハ118の検出温度（△）は、目標温度と一致している。実際に熱処理するウェーハの温度が目標温度と一致したことで、熱処理の品質を向上させることができる。ただし、上記の例において、熱電対付きウェーハ118の検出温度を5℃高くするために、カスケード熱電対に対する目標温度に5℃を補正值として加えても、熱電対付きウェーハの検出温度が、実際に5℃高くならない場合が多く、数回の調整作業の繰り返しが必要となる。

【0008】さらに、図7の構成において、熱電対付きウェーハ118は、加熱ゾーン毎に設置されたヒータ熱電対115およびカスケード熱電対116に対応する位置にそれぞれ配置されていたが、それ以外のウェーハの温度を測定するために、図8のように、熱電対付きウェーハを複数枚増加して配置し、それらによって検出された温度を同様に、温度コントローラ119に取り込んだ場合の、カスケード熱電対と熱電対付きウェーハの検出温度の関係の1例が図11に示すように考えられる。この場合、各加熱ゾーンを代表する位置に配置された熱電対付きウェーハ118の検出温度（△）は、目標温度と一致しているが、それ以外の位置に配置された熱電対付きウェーハの検出温度（▲）は、目標温度に対し誤差を生じている。これでは、熱処理の品質に違いが出てしまい、製品として一定レベル以上の品質を保証できる成果物の製造割合が低下する原因となる。この対策として、ウェーハ領域の温度差をなるべく無くし、均一にするよう、カスケード熱電対116に対する目標温度をさらに補正する方法がある。

【0009】例えば、図11におけるように、CLゾーンとLゾーンとの間に設置した熱電対付きウェーハの検

出温度が、目標温度に対して3℃高い場合、1℃程度、CLゾーンとLゾーンとのカスケード熱電対に対する目標温度から、補正值として減ずる。この場合、補正值を3℃とせずに1℃程度としたのは、先程と同じように誤差の3℃を、カスケード熱電対に対する目標温度の補正值として使用すると、こんどは、加熱ゾーンに対応した熱電対付きウェーハの検出温度が、目標温度に対して誤差が大きくなってしまい、結果的に、ウェーハ領域の温度差を無くすという目的が達成できないからである。さらに、補正值を1℃程度としたのは、CLゾーンとLゾーンとの間に設置した熱電対付きウェーハの検出温度は、CLゾーンとLゾーンのそれぞれへの補正の影響を受けるために、加熱ゾーン間の干渉の度合い等の情報が不明確な場合には、何度も補正值を調整する必要があるので、先ず、その初期値を1℃程度とする意味である。

【0010】図8に示されるように構成した場合、全ての熱電対付きウェーハの検出温度が、目標温度に対する誤差を小さくするように調整（例えば、熟練作業者によって調整）された場合における、カスケード熱電対と熱電対付きウェーハとの検出温度の関係の1例を図12に示す。この場合、加熱ゾーンに対応した熱電対付きウェーハの検出温度（△）は、目標温度に若干一致しなくなつたが、全ての熱電対付きウェーハ（△、▲）における目標温度との誤差が、図11の場合に比べて全体として減少している（矢印で示されるばらつきの幅が小さい）。これにより、製品として一定レベル以上の品質を保証できる成果物の数を増加させることができる。しかし、図12のように、熱電対付きウェーハにおける目標温度との誤差を全体的に小さくするには、熟練した作業者の存在が必要であり、また熟練作業者でも何度も繰り返し調整をするために、多くの調整時間を必要としているのが現状である。

【0011】

【発明が解決しようとする課題】上述の従来の熱処理装置用均熱調整方法は、熱処理装置のウェーハ領域を複数の加熱ゾーンに分割し、全加熱ゾーンに関して、実際に目標温度を設定して温度制御を行う領域の温度を炉周辺のカスケード熱電対等の温度検出装置により検出し、検出した温度により、炉内に配置された被処理体が目標温度で処理されるように加熱制御しようとしているが、温度検出装置に対する設定温度の決定は、熟練作業者の経験や試行に依存しているため、該当する能力のある人員に制限があり、設定時間も多大に必要となるという問題がある。

【0012】この発明は、上記の問題を解決すべくなされたものであって、熟練作業者がいなくても、被処理物の全領域に渡って、簡単に短時間で、かつ誤差を小さくして目標温度に調整（均熱調整）することができ、コンピュータシステムにより自動化も容易に行い得る温度制御方法、熱処理装置及び半導体装置の製造方法を提供す

ることを目的とする。

【0013】

【課題を解決するための手段】上述した課題を解決するため、本発明に係る温度制御方法は、所定位置での検出温度をその目標温度とするよう、少なくとも2つの加熱ゾーンを有する加熱装置を制御する温度制御方法であつて、前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおいて少なくとも1つの所定位置での温度を検出し、検出された複数の所定位置における検出温度の最大値と最小値の間に前記目標温度が含まれるように前記加熱装置を制御することを特徴とするものである。

【0014】このような構成によれば、熟練作業者がいなくても、被処理物の全領域に渡って、簡単に短時間で、かつ誤差を小さくして目標温度に調整（均熱調整）することができる。本発明は、例えば、複数の加熱ゾーンを有し、また、複数の熱電対付きウェーハ位置での温度が検出され得る縦型CVD装置や枚葉装置等に容易に適用できる。

【0015】また、本発明の温度制御方法において、各ゾーンに対応する第1の所定位置に第1の温度検出器を備え、前記第1の温度検出器による検出温度を第1の目標温度とするように前記加熱装置を制御する温度制御方法に用いられ、第1の所定位置よりも被処理物に近い第2の所定位置に第2の温度検出器を備え、前記第1の温度検出器における前記第1の目標温度を変化させた場合に、前記第2の温度検出器の検出温度が変化する度合いを示す係数の行列である干渉行列M、及び前記第2の温度検出器における第2の目標温度と前記第2の温度検出器による検出温度との差P₀を取得し、これら干渉行列Mと誤差P₀に基づいて、前記第1の目標温度を補正することを特徴とするものである。

【0016】このような構成によれば、熟練作業者がいなくても、被処理物の全領域に渡って、簡単に短時間で、かつ誤差を小さくして目標温度に調整（均熱調整）することができ、コンピュータシステムにより自動化も容易に行い得る。なお、実施の形態において第1の温度検出器にはカスケード熱電対が相当し、第2の温度検出器には、ウェーハ（熱電対付きウェーハ）に付けられた熱電対が相当する。そして、この構成によれば、一度取得した干渉行列Mと誤差P₀に基づいて、カスケード熱電対の目標温度が補正されつつ温度制御がなされる。

【0017】また、本発明の温度制御方法は、前記補正された第1の目標温度を用いて温度制御を行うことで、新たな誤差P_{0'}を求め、この誤差P_{0'}と前記干渉行列Mを用いて、前記補正された前記第1の目標温度をさらに補正することを特徴とするものである。

【0018】このような構成によれば、より精度良く温度制御を行え、被処理物をより精度良く所望温度に加熱することができる。

【0019】また、本発明の温度制御方法は、処理室

と、少なくとも1つの加熱ゾーンを有し、前記処理室内に設けられた被処理物を加熱する加熱装置と、前記加熱装置による加熱温度を第1の所定位置にて検出するため、各ゾーンに少なくとも1つ設けた第1の温度検出器とを備え、前記第1の温度検出器により検出された第1の検出温度と、該第1の検出温度についての第1の目標温度とに基づいて前記加熱装置を制御する温度制御方法において、前記加熱ゾーンの数よりも多く、第1の所定位置よりも被処理物に近い第2の所定位置において前記加熱装置による加熱温度を検出する複数の第2の温度検出器と備え、前記第2の温度検出器により検出される第2の検出温度と該第2の検出温度についての第2の目標温度とを比較して前記第1の目標温度の補正值を取得し、前記補正值により前記第1の目標温度を補正して温度制御を行うことを特徴とするものである。

【0020】また、本発明の温度制御方法において、前記補正值の取得は、実際に被処理基板を処理する実プロセス前に行われることを特徴とするものである。

【0021】このような構成によれば、実プロセス中においては、第2の温度検出器を設ける必要が無く、温度検出器を設けることによる被処理物への悪影響をなくすことができる。

【0022】また、本発明に係る熱処理装置は、処理室と、所定位置での検出温度をその目標温度とするよう温度制御される、少なくとも2つの加熱ゾーンを有する加熱装置と、前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおける少なくとも1つの所定位置における温度を検出する複数の温度検出器と、前記複数の温度検出器による複数の検出温度の最大値と最小値の間に前記目標温度が含まれるように、前記加熱装置を制御する制御装置とを備えてなるものである。

【0023】このような構成によれば、熟練作業者がいなくても、被処理物の全領域に渡って、簡単に短時間で、かつ誤差を小さくして目標温度に調整（均熱調整）することができる熱処理装置が提供できる。

【0024】また、本発明に係る半導体装置の製造方法は、所定位置での検出温度をその目標温度とするよう、少なくとも2つの加熱ゾーンを有する加熱装置を制御し、被処理基板に加熱処理を施す半導体装置の製造方法であって、前記加熱ゾーンの数よりも多く、且つ各加熱ゾーンにおける少なくとも1つの所定位置における温度を検出し、検出された複数の所定位置における検出温度の最大値と最小値との間に前記目標温度が含まれるように前記加熱装置を制御することを特徴とするものである。

【0025】このような構成によれば、熟練作業者がいなくても、被処理物の全領域に渡って、簡単に短時間で、かつ誤差を小さくして目標温度に調整（均熱調整）することができる半導体装置の製造方法を提供できる。

【0026】

【発明の実施の形態】以下、この発明の実施の形態について添付図面に基づいて説明する。本発明の最も基本的な形態は、所定位置での検出温度をその目標温度とするよう、少なくとも1つの加熱ゾーンを有する加熱装置を制御する温度制御方法において、前記加熱ゾーンの数よりも多い複数の所定位置での温度を検出し、検出された複数の検出温度の最大値と最小値の間に前記目標温度が含まれるように前記加熱装置を制御することであるが、以下に説明する実施の形態においては、これを基本構成として、更に複数の検出温度と目標温度との差の平均値が最小となるように温度制御を行う場合の形態について説明する。

【0027】実施の形態1. 図1は、この発明の温度制御方法が適用された熱処理装置の実施の形態である縦型拡散炉を示す構成図、図2は、図1の縦型拡散炉の外壁の内部を示す拡大図である。図1および図2に示した縦型拡散炉10は、外壁11の中に配置された均熱管12と反応管13と、炉内を加熱するためのヒータ14と、ヒータ14の温度を検出するヒータ熱電対15a, 15b, 15c, 15dと、均熱管12と反応管13との間の温度を検出するカスケード熱電対16a, 16b, 16c, 16dと、ウェーハ温度（ウェーハおよびウェーハの配置された領域の温度）を検出するための熱電対付きウェーハ18a, 18a', 18b, 18b', 18b'', 18c, 18c', 18dを含む複数のウェーハを搭載したポート17と、ヒータ熱電対15a, 15b, 15c, 15dおよびカスケード熱電対16a, 16b, 16c, 16dの検出温度と目標温度Yとからヒータ14への操作量Z（電力値）を求める温度コントローラ19とから構成されている。なお、上記構成において、カスケード熱電対16a, 16b, 16c, 16dは、本発明の第1の温度検出器を構成し、熱電対付きウェーハ18a, 18a', 18b, 18b', 18b'', 18c, 18c', 18dにおける熱電対は、本発明の第2の温度検出器を構成している。

【0028】上述の例においては、炉内のウェーハ領域の温度を高精度に制御するために、炉内は、4つの加熱ゾーン、すなわち、上部から順にU, CU, CL, Lゾーンに分割されている。各ゾーンにおいては、図示しないこれらのヒータ端子間に高周波電力が印加可能とされており、各ゾーン毎に高周波電力量を変えて印可することができる。これにより各ゾーン毎に温度制御が可能であり、全ゾーンに亘って均一に、または所望する温度勾配を付けて温度調整することが可能である。そして、これらのU, CU, CL, Lゾーンのそれぞれに対応して、ヒータ熱電対15a, 15b, 15c, 15dとカスケード熱電対16a, 16b, 16c, 16dとがそれぞれ設置されている。また、ポート17に搭載されたウェーハのうち、これらのU, CU, CL, Lゾーンを代表する位置に、熱電対付きウェーハが1枚ずつ（18

a, 18 b, 18 c, 18 d)、U, CUゾーン間およびCL, Lゾーン間にはそれぞれ1枚ずつ、CU, CLゾーン間には2枚の合計8枚が配置されている。

【0029】この縦型拡散炉10におけるウェーハ領域の均熱調整方法においては、まず、実際に製品(半導体装置)を製造する前準備として、製品製造に際して行われる温度制御における目標温度の補正值を取得することから行われる。この目標温度の補正值は、ウェーハ領域の温度を均熱するためにカスケード熱電対の検出温度の目標温度に対して用いられる。すなわち、実際の製品製造に際して行われる温度制御においては、熱電対付きウェーハの位置には通常の製品用のウェーハが配置され、ウェーハそのものの温度検出はできない。そこで、温度コントローラ19は、常時配置されているカスケード熱電対16a, 16b, 16c, 16dの検出温度の目標温度に対して、上記補正值を適用した温度制御を行うことにより、ウェーハ領域の温度を均熱にする温度制御を行うことができる。もちろん、何らかの方法でウェーハ領域の温度を常時測定できる構成であれば、それをカスケード熱電対の代わりに制御することで制御性能を向上させることはいうまでもない。

【0030】次に、縦型拡散炉10のウェーハ領域に対する均熱調整方法の原理について順番に説明する。先ず、制御に使用するカスケード熱電対16a, 16b, 16c, 16dの検出温度と、均熱調整の目的であるウェーハ領域の温度を検出するために配置された熱電対付きウェーハ18a, 18a', 18b, 18b', 18b'', 18c, 18c', 18dの検出温度との関係を把握することが必要である。上述の縦型拡散炉10において、8枚の熱電対付きウェーハの検出温度は、4つの加熱ゾーンであるU, CU, CL, Lゾーンに対応するヒータ熱電対15a, 15b, 15c, 15dに温度検出されるヒータ14からの影響を受ける。その影響の度合いを、以下に述べるような方法で数値化する。

【0031】先ず、4つの加熱ゾーンであるU, CU, CL, Lゾーンに対応するカスケード熱電対16a, 16b, 16c, 16dの検出温度をウェーハ処理の目標温度と一致するように制御する。このとき、厳密に目標温度と同じである必要はないが、温度変化は、通常、制御を行う温度帯によって異なる特性を示すために、該当する目標温度から大きく離れない温度帯で影響度合いを数値化する必要がある。全てのゾーンの温度が安定した後に、1つのゾーン、例えば、Uゾーンのカスケード熱電対に対する目標温度に数℃(例えば、10℃)を加え

$$\Delta P_1 = (\alpha_{U1} \times \Delta T_U) + (\alpha_{CU1} \times \Delta T_{CU}) + (\alpha_{CL1} \times \Delta T_{CL}) + (\alpha_{L1} \times \Delta T_L)$$

$$\vdots$$

$$\Delta P_8 = (\alpha_{U8} \times \Delta T_U) + (\alpha_{CU8} \times \Delta T_{CU}) + (\alpha_{CL8} \times \Delta T_{CL}) + (\alpha_{L8} \times \Delta T_L)$$

【0039】となり、8枚の熱電対付きウェーハの検出温度の変化量は、各ゾーンのカスケード熱電対に対する

る。その後、十分に時間が経過し、温度が安定したときの8枚の熱電対付きウェーハの検出温度の変化量(温度が上昇した場合には正、下降した場合には負の数として扱う)を記録する。この結果から、Uゾーンのカスケード熱電対に対する目標温度に加えた変化量を ΔT_U とし、そのときの8枚の熱電対付きウェーハの検出温度の変化量を、上部から順に $\Delta P_{U1} \sim \Delta P_{U8}$ とするなど、以下のように表すことができる。すなわち、

$$[\text{0032}] \Delta P_{U1} = \alpha_{U1} \times \Delta T_U$$

$$\Delta P_{U2} = \alpha_{U2} \times \Delta T_U$$

$$\dots = \dots$$

$$\dots = \dots$$

$$\Delta P_{U8} = \alpha_{U8} \times \Delta T_U$$

【0033】上述の場合、 $\alpha_{U1} \sim \alpha_{U8}$ は、Uゾーンのカスケード熱電対に対する目標温度の変化が、8枚の熱電対付きウェーハの検出温度に与える影響の度合いを示す係数であり、数値が大きいほど影響が大きいことを表す。同様に、CUゾーンのカスケード熱電対に対する目標温度に加えた変化量を ΔT_{CU} とし、そのときの8枚の熱電対付きウェーハ18の検出温度の変化量を、上部から順に $\Delta P_{CU1} \sim \Delta P_{CU8}$ とするなど、以下のように表すことができる。すなわち、

$$[\text{0034}] \Delta P_{CU1} = \alpha_{CU1} \times \Delta T_{CU}$$

$$\Delta P_{CU2} = \alpha_{CU2} \times \Delta T_{CU}$$

$$\dots = \dots$$

$$\dots = \dots$$

$$\Delta P_{CU8} = \alpha_{CU8} \times \Delta T_{CU}$$

【0035】また、CLゾーンについては、

$$\Delta P_{CL1} = \alpha_{CL1} \times \Delta T_{CL}$$

$$\Delta P_{CL2} = \alpha_{CL2} \times \Delta T_{CL}$$

$$\dots = \dots$$

$$\dots = \dots$$

$$\Delta P_{CL8} = \alpha_{CL8} \times \Delta T_{CL}$$

【0036】さらに、Lゾーンについては、

$$\Delta P_{L1} = \alpha_{L1} \times \Delta T_L$$

$$\Delta P_{L2} = \alpha_{L2} \times \Delta T_L$$

$$\dots = \dots$$

$$\dots = \dots$$

$$\Delta P_{L8} = \alpha_{L8} \times \Delta T_L$$

と表すことができる。

【0037】上述の結果から、8枚の熱電対付きウェーハの検出温度の変化量を $\Delta P_1 \sim \Delta P_8$ とすると、

【0038】

【数1】

目標温度の変化を係数倍したものの和で表すことができる。したがって、8枚の熱電対付きウェーハの検出温度

を、目標温度に近付けるように変化させるためには、上記の関係式を利用し、各ゾーンのカスケード熱電対に対する目標温度への補正值を決定する必要がある。上記の関係式を行列式によって表せば、次式(1)のようになる。

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta P_5 \\ \Delta P_6 \\ \Delta P_7 \\ \Delta P_8 \end{bmatrix} = \begin{bmatrix} \alpha_{v1} & \alpha_{cv1} & \alpha_{cl1} & \alpha_{l1} \\ \alpha_{v2} & \alpha_{cv2} & \alpha_{cl2} & \alpha_{l2} \\ \alpha_{v3} & \alpha_{cv3} & \alpha_{cl3} & \alpha_{l3} \\ \alpha_{v4} & \alpha_{cv4} & \alpha_{cl4} & \alpha_{l4} \\ \alpha_{v5} & \alpha_{cv5} & \alpha_{cl5} & \alpha_{l5} \\ \alpha_{v6} & \alpha_{cv6} & \alpha_{cl6} & \alpha_{l6} \\ \alpha_{v7} & \alpha_{cv7} & \alpha_{cl7} & \alpha_{l7} \\ \alpha_{v8} & \alpha_{cv8} & \alpha_{cl8} & \alpha_{l8} \end{bmatrix} \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} \quad \dots \dots (1)$$

【0041】上記の式(1)において、右辺の第1項の行列を干渉行列(カスケード熱電対に対する目標温度の変化が、熱電対付きウェーハの検出温度に与える影響の度合いを示す係数の行列)と呼び、Mとし、右辺の第2項の列ベクトル(カスケード熱電対に対する目標温度の変化量)を ΔC とし、左辺の列ベクトル(熱電対付きウェーハの検出温度の変化量)を ΔP と表すと、上記の式(1)は、

$$[0042] \Delta P = M \times \Delta C \quad \dots \dots (2)$$

【0043】となる。このようにして、制御に使用するカスケード熱電対と、目的である熱電対付きウェーハの検出温度の関係について、数値化することができる。ただし、この数値は、様々な要因により誤差を含んでいる場合があるので、より精度を高める必要がある場合や、調整時間に余裕がある場合には、上記の干渉行列の作成

$$P_0 = \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{bmatrix} \quad \dots \dots (3)$$

【0046】次に、実際に8枚の熱電対付きウェーハ18a, 18a', 18b, 18b', 18b'', 18c, 18c', 18dによる検出温度を、目標温度に近付けるための調整を行う。調整を行う際に、目的である8枚の熱電対付きウェーハの検出温度が、どれだけ目標温度に近付いたかを評価するための評価基準が必要となる。そこで、製品として一定レベル以上の品質を保証できる成果物の数を増加させることを目的として、8枚の熱電対付きウェーハの全てにおいて、目標温度に対する誤差が最小になるように、各熱電対付きウェーハの検出温度と、目標温度との誤差の2乗の和を評価式とし、これが最小となるように調整する。他の評価基準、例えば、誤差の絶対値の和を最小にするように調整する場合にも、これから記述する方法を応用することができる。

【0040】
【数2】

を数回実行してその平均値を使用してもよいことはいうまでもない。

【0044】次に、実際に調整を行う前に、カスケード熱電対の検出温度を、ウェーハ処理の目標温度と一致するように制御した場合の、各熱電対付きウェーハの検出温度と、目標温度との誤差を取得する。このとき、各熱電対付きウェーハの検出温度が、目標温度よりも高い場合には、誤差を正の数とし、目標温度よりも低い場合には、誤差を負の数として扱う。8枚の熱電対付きウェーハの検出温度と、目標温度との誤差を、上部の加熱ゾーンから順に $E_1 \sim E_8$ とし、下記の式(3)のような列ベクトル P_0 として表すことができる。

$$[0045]$$

【数3】

上述した評価式を示すと、

$$[0047] J = |P_0 + \Delta P|^2 \quad \dots \dots (4)$$

【0048】となる。この評価式Jにおける右辺の内容は、調整前の8枚の熱電対付きウェーハの検出温度と目標温度との誤差である P_0 と、調整によって変化する8枚の熱電対付きウェーハの検出温度の変化量である ΔP の和を表し、調整後の8枚の熱電対付きウェーハの検出温度と、目標温度との誤差を表している。上記の評価式J(式(4))に先述の式(2)を適用すると、

$$[0049]$$

$$J = |P_0 + [M \times \Delta C]|^2 \quad \dots \dots (5)$$

【0050】となり、行列の転置を用いると、

【0051】

$$J = [P_0 + [M \times \Delta C]]^T \times [P_0 + [M \times \Delta C]] \quad \dots \quad (6)$$

【0052】となる（「 T 」は、行列の転置を表す）。

さらに、先述の式(1)および式(3)を用いると、下記の式(7)のようになる。

【0053】

【数4】

$J =$

$$\begin{aligned} & \left[\begin{array}{c} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{array} \right] \left[\begin{array}{cccc} \alpha_{U1} & \alpha_{CU1} & \alpha_{CL1} & \alpha_{L1} \\ \alpha_{U2} & \alpha_{CU2} & \alpha_{CL2} & \alpha_{L2} \\ \alpha_{U3} & \alpha_{CU3} & \alpha_{CL3} & \alpha_{L3} \\ \alpha_{U4} & \alpha_{CU4} & \alpha_{CL4} & \alpha_{L4} \\ \alpha_{U5} & \alpha_{CU5} & \alpha_{CL5} & \alpha_{L5} \\ \alpha_{U6} & \alpha_{CU6} & \alpha_{CL6} & \alpha_{L6} \\ \alpha_{U7} & \alpha_{CU7} & \alpha_{CL7} & \alpha_{L7} \\ \alpha_{U8} & \alpha_{CU8} & \alpha_{CL8} & \alpha_{L8} \end{array} \right] \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} \times \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{bmatrix} \left[\begin{array}{cccc} \alpha_{U1} & \alpha_{CU1} & \alpha_{CL1} & \alpha_{L1} \\ \alpha_{U2} & \alpha_{CU2} & \alpha_{CL2} & \alpha_{L2} \\ \alpha_{U3} & \alpha_{CU3} & \alpha_{CL3} & \alpha_{L3} \\ \alpha_{U4} & \alpha_{CU4} & \alpha_{CL4} & \alpha_{L4} \\ \alpha_{U5} & \alpha_{CU5} & \alpha_{CL5} & \alpha_{L5} \\ \alpha_{U6} & \alpha_{CU6} & \alpha_{CL6} & \alpha_{L6} \\ \alpha_{U7} & \alpha_{CU7} & \alpha_{CL7} & \alpha_{L7} \\ \alpha_{U8} & \alpha_{CU8} & \alpha_{CL8} & \alpha_{L8} \end{array} \right] \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} \\ & - \left[\begin{array}{c} E_1 + \alpha_{U1} \times \Delta T_U + \alpha_{CU1} \times \Delta T_{CU} + \alpha_{CL1} \times \Delta T_{CL} + \alpha_{L1} \times \Delta T_L \\ E_2 + \alpha_{U2} \times \Delta T_U + \alpha_{CU2} \times \Delta T_{CU} + \alpha_{CL2} \times \Delta T_{CL} + \alpha_{L2} \times \Delta T_L \\ E_3 + \alpha_{U3} \times \Delta T_U + \alpha_{CU3} \times \Delta T_{CU} + \alpha_{CL3} \times \Delta T_{CL} + \alpha_{L3} \times \Delta T_L \\ E_4 + \alpha_{U4} \times \Delta T_U + \alpha_{CU4} \times \Delta T_{CU} + \alpha_{CL4} \times \Delta T_{CL} + \alpha_{L4} \times \Delta T_L \\ E_5 + \alpha_{U5} \times \Delta T_U + \alpha_{CU5} \times \Delta T_{CU} + \alpha_{CL5} \times \Delta T_{CL} + \alpha_{L5} \times \Delta T_L \\ E_6 + \alpha_{U6} \times \Delta T_U + \alpha_{CU6} \times \Delta T_{CU} + \alpha_{CL6} \times \Delta T_{CL} + \alpha_{L6} \times \Delta T_L \\ E_7 + \alpha_{U7} \times \Delta T_U + \alpha_{CU7} \times \Delta T_{CU} + \alpha_{CL7} \times \Delta T_{CL} + \alpha_{L7} \times \Delta T_L \\ E_8 + \alpha_{U8} \times \Delta T_U + \alpha_{CU8} \times \Delta T_{CU} + \alpha_{CL8} \times \Delta T_{CL} + \alpha_{L8} \times \Delta T_L \end{array} \right]^T \\ & \times \left[\begin{array}{c} E_1 + \alpha_{U1} \times \Delta T_U + \alpha_{CU1} \times \Delta T_{CU} + \alpha_{CL1} \times \Delta T_{CL} + \alpha_{L1} \times \Delta T_L \\ E_2 + \alpha_{U2} \times \Delta T_U + \alpha_{CU2} \times \Delta T_{CU} + \alpha_{CL2} \times \Delta T_{CL} + \alpha_{L2} \times \Delta T_L \\ E_3 + \alpha_{U3} \times \Delta T_U + \alpha_{CU3} \times \Delta T_{CU} + \alpha_{CL3} \times \Delta T_{CL} + \alpha_{L3} \times \Delta T_L \\ E_4 + \alpha_{U4} \times \Delta T_U + \alpha_{CU4} \times \Delta T_{CU} + \alpha_{CL4} \times \Delta T_{CL} + \alpha_{L4} \times \Delta T_L \\ E_5 + \alpha_{U5} \times \Delta T_U + \alpha_{CU5} \times \Delta T_{CU} + \alpha_{CL5} \times \Delta T_{CL} + \alpha_{L5} \times \Delta T_L \\ E_6 + \alpha_{U6} \times \Delta T_U + \alpha_{CU6} \times \Delta T_{CU} + \alpha_{CL6} \times \Delta T_{CL} + \alpha_{L6} \times \Delta T_L \\ E_7 + \alpha_{U7} \times \Delta T_U + \alpha_{CU7} \times \Delta T_{CU} + \alpha_{CL7} \times \Delta T_{CL} + \alpha_{L7} \times \Delta T_L \\ E_8 + \alpha_{U8} \times \Delta T_U + \alpha_{CU8} \times \Delta T_{CU} + \alpha_{CL8} \times \Delta T_{CL} + \alpha_{L8} \times \Delta T_L \end{array} \right] \\ & - (E_1 + \alpha_{U1} \times \Delta T_U + \alpha_{CU1} \times \Delta T_{CU} + \alpha_{CL1} \times \Delta T_{CL} + \alpha_{L1} \times \Delta T_L)^2 \\ & + (E_2 + \alpha_{U2} \times \Delta T_U + \alpha_{CU2} \times \Delta T_{CU} + \alpha_{CL2} \times \Delta T_{CL} + \alpha_{L2} \times \Delta T_L)^2 \\ & + (E_3 + \alpha_{U3} \times \Delta T_U + \alpha_{CU3} \times \Delta T_{CU} + \alpha_{CL3} \times \Delta T_{CL} + \alpha_{L3} \times \Delta T_L)^2 \\ & + (E_4 + \alpha_{U4} \times \Delta T_U + \alpha_{CU4} \times \Delta T_{CU} + \alpha_{CL4} \times \Delta T_{CL} + \alpha_{L4} \times \Delta T_L)^2 \\ & + (E_5 + \alpha_{U5} \times \Delta T_U + \alpha_{CU5} \times \Delta T_{CU} + \alpha_{CL5} \times \Delta T_{CL} + \alpha_{L5} \times \Delta T_L)^2 \\ & + (E_6 + \alpha_{U6} \times \Delta T_U + \alpha_{CU6} \times \Delta T_{CU} + \alpha_{CL6} \times \Delta T_{CL} + \alpha_{L6} \times \Delta T_L)^2 \\ & + (E_7 + \alpha_{U7} \times \Delta T_U + \alpha_{CU7} \times \Delta T_{CU} + \alpha_{CL7} \times \Delta T_{CL} + \alpha_{L7} \times \Delta T_L)^2 \\ & + (E_8 + \alpha_{U8} \times \Delta T_U + \alpha_{CU8} \times \Delta T_{CU} + \alpha_{CL8} \times \Delta T_{CL} + \alpha_{L8} \times \Delta T_L)^2 \quad \dots \quad (7) \end{aligned}$$

【0054】次に、評価式 J を最小にすべく ΔC の各要素 ΔT_U , ΔT_{CU} , ΔT_{CL} , ΔT_L を求めるために、評価式 J を、 ΔC の各要素 ΔT_U , ΔT_{CU} , ΔT_{CL} , ΔT_L について偏微分する。先ず、評価式 J を ΔT_U について偏

微分すると、次式(8)となる。

【0055】

【数5】

$$\begin{aligned}
& \frac{\partial J}{\partial \Delta T_U} \\
= & ((2 \times \alpha_{U_1}) \times (E_1 + (\alpha_{U_1} \times \Delta T_U) + (\alpha_{CU_1} \times \Delta T_{CU}) + (\alpha_{CL_1} \times \Delta T_{CL}) + (\alpha_{L_1} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_2}) \times (E_2 + (\alpha_{U_2} \times \Delta T_U) + (\alpha_{CU_2} \times \Delta T_{CU}) + (\alpha_{CL_2} \times \Delta T_{CL}) + (\alpha_{L_2} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_3}) \times (E_3 + (\alpha_{U_3} \times \Delta T_U) + (\alpha_{CU_3} \times \Delta T_{CU}) + (\alpha_{CL_3} \times \Delta T_{CL}) + (\alpha_{L_3} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_4}) \times (E_4 + (\alpha_{U_4} \times \Delta T_U) + (\alpha_{CU_4} \times \Delta T_{CU}) + (\alpha_{CL_4} \times \Delta T_{CL}) + (\alpha_{L_4} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_5}) \times (E_5 + (\alpha_{U_5} \times \Delta T_U) + (\alpha_{CU_5} \times \Delta T_{CU}) + (\alpha_{CL_5} \times \Delta T_{CL}) + (\alpha_{L_5} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_6}) \times (E_6 + (\alpha_{U_6} \times \Delta T_U) + (\alpha_{CU_6} \times \Delta T_{CU}) + (\alpha_{CL_6} \times \Delta T_{CL}) + (\alpha_{L_6} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_7}) \times (E_7 + (\alpha_{U_7} \times \Delta T_U) + (\alpha_{CU_7} \times \Delta T_{CU}) + (\alpha_{CL_7} \times \Delta T_{CL}) + (\alpha_{L_7} \times \Delta T_L))) \\
& + ((2 \times \alpha_{U_8}) \times (E_8 + (\alpha_{U_8} \times \Delta T_U) + (\alpha_{CU_8} \times \Delta T_{CU}) + (\alpha_{CL_8} \times \Delta T_{CL}) + (\alpha_{L_8} \times \Delta T_L))) \\
& - 2 \times \left\{ (\alpha_{U_1}^2 + \alpha_{U_2}^2 + \alpha_{U_3}^2 + \alpha_{U_4}^2 + \alpha_{U_5}^2 + \alpha_{U_6}^2 + \alpha_{U_7}^2 + \alpha_{U_8}^2) \times \Delta T_U \right. \\
& + ((\alpha_{U_1} \times \alpha_{CU_1}) + (\alpha_{U_2} \times \alpha_{CU_2}) + (\alpha_{U_3} \times \alpha_{CU_3}) + (\alpha_{U_4} \times \alpha_{CU_4}) \\
& \quad + (\alpha_{U_5} \times \alpha_{CU_5}) + (\alpha_{U_6} \times \alpha_{CU_6}) + (\alpha_{U_7} \times \alpha_{CU_7}) + (\alpha_{U_8} \times \alpha_{CU_8})) \times \Delta T_{CU} \\
& + ((\alpha_{U_1} \times \alpha_{CL_1}) + (\alpha_{U_2} \times \alpha_{CL_2}) + (\alpha_{U_3} \times \alpha_{CL_3}) + (\alpha_{U_4} \times \alpha_{CL_4}) \\
& \quad + (\alpha_{U_5} \times \alpha_{CL_5}) + (\alpha_{U_6} \times \alpha_{CL_6}) + (\alpha_{U_7} \times \alpha_{CL_7}) + (\alpha_{U_8} \times \alpha_{CL_8})) \times \Delta T_{CL} \\
& + ((\alpha_{U_1} \times \alpha_{L_1}) + (\alpha_{U_2} \times \alpha_{L_2}) + (\alpha_{U_3} \times \alpha_{L_3}) + (\alpha_{U_4} \times \alpha_{L_4}) \\
& \quad + (\alpha_{U_5} \times \alpha_{L_5}) + (\alpha_{U_6} \times \alpha_{L_6}) + (\alpha_{U_7} \times \alpha_{L_7}) + (\alpha_{U_8} \times \alpha_{L_8})) \times \Delta T_L \\
& \quad \left. + ((\alpha_{U_1} \times E_1) + (\alpha_{U_2} \times E_2) + (\alpha_{U_3} \times E_3) + (\alpha_{U_4} \times E_4) \right. \\
& \quad \left. + (\alpha_{U_5} \times E_5) + (\alpha_{U_6} \times E_6) + (\alpha_{U_7} \times E_7) + (\alpha_{U_8} \times E_8)) \right\} \\
& \quad \cdots \cdots (8)
\end{aligned}$$

【0056】上記と同様に、評価式Jを ΔT_{CU} , ΔT_{CL} , ΔT_L についてそれぞれ偏微分すると、次式
(9)、(10)、(11)が得られる。

【0057】

【数6】

$$\begin{aligned} \frac{\partial J}{\partial \Delta T_{CU}} = & 2 \times \{ ((\alpha_{U1} \times \alpha_{CU1}) + (\alpha_{U2} \times \alpha_{CU2}) + (\alpha_{U3} \times \alpha_{CU3}) + (\alpha_{U4} \times \alpha_{CU4}) \\ & + (\alpha_{U5} \times \alpha_{CU5}) + (\alpha_{U6} \times \alpha_{CU6}) + (\alpha_{U7} \times \alpha_{CU7}) + (\alpha_{U8} \times \alpha_{CU8})) \times \Delta T_U \\ & + (\alpha_{CU1}^2 + \alpha_{CU2}^2 + \alpha_{CU3}^2 + \alpha_{CU4}^2 + \alpha_{CU5}^2 + \alpha_{CU6}^2 + \alpha_{CU7}^2 + \alpha_{CU8}^2) \times \Delta T_{CU} \\ & + ((\alpha_{CU1} \times \alpha_{CL1}) + (\alpha_{CU2} \times \alpha_{CL2}) + (\alpha_{CU3} \times \alpha_{CL3}) + (\alpha_{CU4} \times \alpha_{CL4}) \\ & + (\alpha_{CU5} \times \alpha_{CL5}) + (\alpha_{CU6} \times \alpha_{CL6}) + (\alpha_{CU7} \times \alpha_{CL7}) + (\alpha_{CU8} \times \alpha_{CL8})) \times \Delta T_{CL} \\ & + ((\alpha_{CU1} \times \alpha_{L1}) + (\alpha_{CU2} \times \alpha_{L2}) + (\alpha_{CU3} \times \alpha_{L3}) + (\alpha_{CU4} \times \alpha_{L4}) \\ & + (\alpha_{CU5} \times \alpha_{L5}) + (\alpha_{CU6} \times \alpha_{L6}) + (\alpha_{CU7} \times \alpha_{L7}) + (\alpha_{CU8} \times \alpha_{L8})) \times \Delta T_L \\ & + ((\alpha_{CU1} \times E_1) + (\alpha_{CU2} \times E_2) + (\alpha_{CU3} \times E_3) + (\alpha_{CU4} \times E_4) \\ & + (\alpha_{CU5} \times E_5) + (\alpha_{CU6} \times E_6) + (\alpha_{CU7} \times E_7) + (\alpha_{CU8} \times E_8)) \} \end{aligned} \quad \dots \quad (9)$$

$$\begin{aligned} \frac{\partial J}{\partial \Delta T_{CL}} = & 2 \times \{ ((\alpha_{U1} \times \alpha_{CL1}) + (\alpha_{U2} \times \alpha_{CL2}) + (\alpha_{U3} \times \alpha_{CL3}) + (\alpha_{U4} \times \alpha_{CL4}) \\ & + (\alpha_{U5} \times \alpha_{CL5}) + (\alpha_{U6} \times \alpha_{CL6}) + (\alpha_{U7} \times \alpha_{CL7}) + (\alpha_{U8} \times \alpha_{CL8})) \times \Delta T_U \\ & + ((\alpha_{CU1} \times \alpha_{CL1}) + (\alpha_{CU2} \times \alpha_{CL2}) + (\alpha_{CU3} \times \alpha_{CL3}) + (\alpha_{CU4} \times \alpha_{CL4}) \\ & + (\alpha_{CU5} \times \alpha_{CL5}) + (\alpha_{CU6} \times \alpha_{CL6}) + (\alpha_{CU7} \times \alpha_{CL7}) + (\alpha_{CU8} \times \alpha_{CL8})) \times \Delta T_{CU} \\ & + (\alpha_{CL1}^2 + \alpha_{CL2}^2 + \alpha_{CL3}^2 + \alpha_{CL4}^2 + \alpha_{CL5}^2 + \alpha_{CL6}^2 + \alpha_{CL7}^2 + \alpha_{CL8}^2) \times \Delta T_{CL} \\ & + ((\alpha_{CL1} \times \alpha_{L1}) + (\alpha_{CL2} \times \alpha_{L2}) + (\alpha_{CL3} \times \alpha_{L3}) + (\alpha_{CL4} \times \alpha_{L4}) \\ & + (\alpha_{CL5} \times \alpha_{L5}) + (\alpha_{CL6} \times \alpha_{L6}) + (\alpha_{CL7} \times \alpha_{L7}) + (\alpha_{CL8} \times \alpha_{L8})) \times \Delta T_L \\ & + ((\alpha_{CL1} \times E_1) + (\alpha_{CL2} \times E_2) + (\alpha_{CL3} \times E_3) + (\alpha_{CL4} \times E_4) \\ & + (\alpha_{CL5} \times E_5) + (\alpha_{CL6} \times E_6) + (\alpha_{CL7} \times E_7) + (\alpha_{CL8} \times E_8)) \} \end{aligned} \quad \dots \quad (10)$$

$$\begin{aligned} \frac{\partial J}{\partial \Delta T_L} = & 2 \times \{ ((\alpha_{U1} \times \alpha_{L1}) + (\alpha_{U2} \times \alpha_{L2}) + (\alpha_{U3} \times \alpha_{L3}) + (\alpha_{U4} \times \alpha_{L4}) \\ & + (\alpha_{U5} \times \alpha_{L5}) + (\alpha_{U6} \times \alpha_{L6}) + (\alpha_{U7} \times \alpha_{L7}) + (\alpha_{U8} \times \alpha_{L8})) \times \Delta T_U \\ & + ((\alpha_{CU1} \times \alpha_{L1}) + (\alpha_{CU2} \times \alpha_{L2}) + (\alpha_{CU3} \times \alpha_{L3}) + (\alpha_{CU4} \times \alpha_{L4}) \\ & + (\alpha_{CU5} \times \alpha_{L5}) + (\alpha_{CU6} \times \alpha_{L6}) + (\alpha_{CU7} \times \alpha_{L7}) + (\alpha_{CU8} \times \alpha_{L8})) \times \Delta T_{CU} \\ & + ((\alpha_{CL1} \times \alpha_{L1}) + (\alpha_{CL2} \times \alpha_{L2}) + (\alpha_{CL3} \times \alpha_{L3}) + (\alpha_{CL4} \times \alpha_{L4}) \\ & + (\alpha_{CL5} \times \alpha_{L5}) + (\alpha_{CL6} \times \alpha_{L6}) + (\alpha_{CL7} \times \alpha_{L7}) + (\alpha_{CL8} \times \alpha_{L8})) \times \Delta T_{CL} \\ & + (\alpha_{L1}^2 + \alpha_{L2}^2 + \alpha_{L3}^2 + \alpha_{L4}^2 + \alpha_{L5}^2 + \alpha_{L6}^2 + \alpha_{L7}^2 + \alpha_{L8}^2) \times \Delta T_L \\ & + ((\alpha_{L1} \times E_1) + (\alpha_{L2} \times E_2) + (\alpha_{L3} \times E_3) + (\alpha_{L4} \times E_4) \\ & + (\alpha_{L5} \times E_5) + (\alpha_{L6} \times E_6) + (\alpha_{L7} \times E_7) + (\alpha_{L8} \times E_8)) \} \end{aligned} \quad \dots \quad (11)$$

【0058】このように、評価式Jを、 ΔT の各要素 ΔT_U , ΔT_{CU} , ΔT_{CL} , ΔT_L について偏微分した結果に基づき、

$$\partial J / \partial \Delta T_U = 0$$

$$\partial J / \partial \Delta T_{CU} = 0$$

$$\partial J / \partial \Delta T_{CL} = 0$$

$$\partial J / \partial \Delta T_L = 0$$

【0060】とした式は、 ΔC の各要素 ΔT_U , ΔT_{CU} , ΔT_{CL} , ΔT_L を変数とする4元1次の方程式となり、この4式を連立方程式として解いた解、 ΔT_U ,

$$\begin{bmatrix} \alpha_{U1}^2 + \dots + \alpha_{U8}^2 \\ (\alpha_{U1} \times \alpha_{CU1}) + \dots + (\alpha_{U8} \times \alpha_{CU8}) \\ (\alpha_{U1} \times \alpha_{CL1}) + \dots + (\alpha_{U8} \times \alpha_{CL8}) \\ (\alpha_{U1} \times \alpha_{L1}) + \dots + (\alpha_{U8} \times \alpha_{L8}) \end{bmatrix} \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} = (-1) \times ((\alpha_{U1} \times E_1) + \dots + (\alpha_{U8} \times E_8)) \quad \dots \quad (12)$$

【0063】同様に、 $\partial J / \partial \Delta T_{CU} = 0$, $\partial J / \partial \Delta T_{CL} = 0$, $\partial J / \partial \Delta T_L = 0$ とした式は、次式(13)、(14)、(15)として表すことができる。

ΔT_{CU} , ΔT_{CL} , ΔT_L は、評価式Jを最小にするつまり、各熱電対付きウェーハの検出温度と、目標温度との誤差の2乗の和を最小にする、カスケード熱電対に対する目標温度の補正值である。

【0061】次に、上述の4元1次の連立方程式の解法を示す。先ず、 $\partial J / \partial \Delta T_U = 0$ とした式は、次式(12)と表すことができる。

$$[0062]$$

$$[数7]$$

$$[0064]$$

$$[数8]$$

$$\begin{bmatrix} (\alpha_{v_1} \times \alpha_{cv_1}) + \dots + (\alpha_{v_8} \times \alpha_{cv_8}) \\ \alpha_{cv_1}^2 + \dots + \alpha_{cv_8}^2 \\ (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) \\ (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_L \end{bmatrix} = (-1) \times ((\alpha_{cv_1} \times E_1) + \dots + (\alpha_{cv_8} \times E_8)) \quad \dots \dots (13)$$

$$\begin{bmatrix} (\alpha_{v_1} \times \alpha_{cl_1}) + \dots + (\alpha_{v_8} \times \alpha_{cl_8}) \\ (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) \\ \alpha_{cl_1}^2 + \dots + \alpha_{cl_8}^2 \\ (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_L \end{bmatrix} = (-1) \times ((\alpha_{cl_1} \times E_1) + \dots + (\alpha_{cl_8} \times E_8)) \quad \dots \dots (14)$$

$$\begin{bmatrix} (\alpha_{v_1} \times \alpha_{L_1}) + \dots + (\alpha_{v_8} \times \alpha_{L_8}) \\ (\alpha_{cv_1} \times \alpha_{L_1}) + \dots + (\alpha_{cv_8} \times \alpha_{L_8}) \\ (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) \\ \alpha_{L_1}^2 + \dots + \alpha_{L_8}^2 \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_L \end{bmatrix} = (-1) \times ((\alpha_{L_1} \times E_1) + \dots + (\alpha_{L_8} \times E_8)) \quad \dots \dots (15)$$

【0065】上記の4つの式は、行列を用いて、(1
6) 式と表すことができる。

【0066】
【数9】

$$\begin{bmatrix} \alpha_{v_1}^2 + \dots + \alpha_{v_8}^2 & (\alpha_{v_1} \times \alpha_{cv_1}) + \dots + (\alpha_{v_8} \times \alpha_{cv_8}) & (\alpha_{v_1} \times \alpha_{cl_1}) + \dots + (\alpha_{v_8} \times \alpha_{cl_8}) & (\alpha_{v_1} \times \alpha_{L_1}) + \dots + (\alpha_{v_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{cv_1}) + \dots + (\alpha_{v_8} \times \alpha_{cv_8}) & \alpha_{cv_1}^2 + \dots + \alpha_{cv_8}^2 & (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) & (\alpha_{cv_1} \times \alpha_{L_1}) + \dots + (\alpha_{cv_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{cl_1}) + \dots + (\alpha_{v_8} \times \alpha_{cl_8}) & (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) & \alpha_{cl_1}^2 + \dots + \alpha_{cl_8}^2 & (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{L_1}) + \dots + (\alpha_{v_8} \times \alpha_{L_8}) & (\alpha_{cv_1} \times \alpha_{L_1}) + \dots + (\alpha_{cv_8} \times \alpha_{L_8}) & (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) & \alpha_{L_1}^2 + \dots + \alpha_{L_8}^2 \end{bmatrix} \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_L \end{bmatrix}$$

$$= \begin{bmatrix} (-1) \times ((\alpha_{v_1} \times E_1) + \dots + (\alpha_{v_8} \times E_8)) \\ (-1) \times ((\alpha_{cv_1} \times E_1) + \dots + (\alpha_{cv_8} \times E_8)) \\ (-1) \times ((\alpha_{cl_1} \times E_1) + \dots + (\alpha_{cl_8} \times E_8)) \\ (-1) \times ((\alpha_{L_1} \times E_1) + \dots + (\alpha_{L_8} \times E_8)) \end{bmatrix} \quad \dots \dots (16)$$

【0067】上記の式(16)において、左辺の第1項
の行列は、式(2)における干渉行列Mを使用して、
(17) 式と表すことができる。

【0068】
【数10】

$$\begin{bmatrix} \alpha_{v_1}^2 + \dots + \alpha_{v_8}^2 & (\alpha_{v_1} \times \alpha_{cv_1}) + \dots + (\alpha_{v_8} \times \alpha_{cv_8}) & (\alpha_{v_1} \times \alpha_{cl_1}) + \dots + (\alpha_{v_8} \times \alpha_{cl_8}) & (\alpha_{v_1} \times \alpha_{L_1}) + \dots + (\alpha_{v_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{cv_1}) + \dots + (\alpha_{v_8} \times \alpha_{cv_8}) & \alpha_{cv_1}^2 + \dots + \alpha_{cv_8}^2 & (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) & (\alpha_{cv_1} \times \alpha_{L_1}) + \dots + (\alpha_{cv_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{cl_1}) + \dots + (\alpha_{v_8} \times \alpha_{cl_8}) & (\alpha_{cv_1} \times \alpha_{cl_1}) + \dots + (\alpha_{cv_8} \times \alpha_{cl_8}) & \alpha_{cl_1}^2 + \dots + \alpha_{cl_8}^2 & (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) \\ (\alpha_{v_1} \times \alpha_{L_1}) + \dots + (\alpha_{v_8} \times \alpha_{L_8}) & (\alpha_{cv_1} \times \alpha_{L_1}) + \dots + (\alpha_{cv_8} \times \alpha_{L_8}) & (\alpha_{cl_1} \times \alpha_{L_1}) + \dots + (\alpha_{cl_8} \times \alpha_{L_8}) & \alpha_{L_1}^2 + \dots + \alpha_{L_8}^2 \end{bmatrix}$$

$$= \begin{bmatrix} \alpha_{v_1} & \alpha_{cv_1} & \alpha_{cl_1} & \alpha_{L_1} \\ \alpha_{v_2} & \alpha_{cv_2} & \alpha_{cl_2} & \alpha_{L_2} \\ \alpha_{v_3} & \alpha_{cv_3} & \alpha_{cl_3} & \alpha_{L_3} \\ \alpha_{v_4} & \alpha_{cv_4} & \alpha_{cl_4} & \alpha_{L_4} \\ \alpha_{v_5} & \alpha_{cv_5} & \alpha_{cl_5} & \alpha_{L_5} \\ \alpha_{v_6} & \alpha_{cv_6} & \alpha_{cl_6} & \alpha_{L_6} \\ \alpha_{v_7} & \alpha_{cv_7} & \alpha_{cl_7} & \alpha_{L_7} \\ \alpha_{v_8} & \alpha_{cv_8} & \alpha_{cl_8} & \alpha_{L_8} \end{bmatrix}^T \times \begin{bmatrix} \alpha_{v_1} & \alpha_{cv_1} & \alpha_{cl_1} & \alpha_{L_1} \\ \alpha_{v_2} & \alpha_{cv_2} & \alpha_{cl_2} & \alpha_{L_2} \\ \alpha_{v_3} & \alpha_{cv_3} & \alpha_{cl_3} & \alpha_{L_3} \\ \alpha_{v_4} & \alpha_{cv_4} & \alpha_{cl_4} & \alpha_{L_4} \\ \alpha_{v_5} & \alpha_{cv_5} & \alpha_{cl_5} & \alpha_{L_5} \\ \alpha_{v_6} & \alpha_{cv_6} & \alpha_{cl_6} & \alpha_{L_6} \\ \alpha_{v_7} & \alpha_{cv_7} & \alpha_{cl_7} & \alpha_{L_7} \\ \alpha_{v_8} & \alpha_{cv_8} & \alpha_{cl_8} & \alpha_{L_8} \end{bmatrix} = M^T \times M \quad \dots \dots (17)$$

【0069】また、右辺の列ベクトルは、式(2)における干渉行列Mおよび式(3)における調整前の8枚の熱電対付きウェーハの検出温度と目標温度との誤差P₀

を使用して、(18)式と表すことができる。

【0070】

【数11】

$$\begin{aligned}
 & \left[(-1) \times ((\alpha_{U1} \times E_1) + \dots + (\alpha_{U8} \times E_8)) \right] \\
 & \left[(-1) \times ((\alpha_{CU1} \times E_1) + \dots + (\alpha_{CU8} \times E_8)) \right] \\
 & \left[(-1) \times ((\alpha_{CL1} \times E_1) + \dots + (\alpha_{CL8} \times E_8)) \right] \\
 & \left[(-1) \times ((\alpha_{L1} \times E_1) + \dots + (\alpha_{L8} \times E_8)) \right] \\
 \\
 & - (-1) \times \begin{bmatrix} \alpha_{U1} & \alpha_{CU1} & \alpha_{CL1} & \alpha_{L1} \\ \alpha_{U2} & \alpha_{CU2} & \alpha_{CL2} & \alpha_{L2} \\ \alpha_{U3} & \alpha_{CU3} & \alpha_{CL3} & \alpha_{L3} \\ \alpha_{U4} & \alpha_{CU4} & \alpha_{CL4} & \alpha_{L4} \\ \alpha_{U5} & \alpha_{CU5} & \alpha_{CL5} & \alpha_{L5} \\ \alpha_{U6} & \alpha_{CU6} & \alpha_{CL6} & \alpha_{L6} \\ \alpha_{U7} & \alpha_{CU7} & \alpha_{CL7} & \alpha_{L7} \\ \alpha_{U8} & \alpha_{CU8} & \alpha_{CL8} & \alpha_{L8} \end{bmatrix}^T \times \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{bmatrix} \\
 \\
 & = (-1) \times M^T \times P_0 \quad \dots \dots (18)
 \end{aligned}$$

【0071】したがって、式(16)の連立方程式は、(19)式と表すことができる。

【0072】

【数12】

$$[M^T \times M] \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} = (-1) \times M^T \times P_0 \quad \dots \dots (19)$$

【0073】両辺の左から逆行列 [M^T × M]⁻¹を掛けると、(20)式となる。

【0074】

【数13】

$$\begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} = [M^T \times M]^{-1} \times (-1) \times M^T \times P_0 \quad \dots \dots (20)$$

【0075】式(20)の右辺におけるMおよびP₀は、干渉行列および調整前の8枚の熱電対付きウェーハの検出温度と目標温度との誤差として既に取得した数値であるので、その値を式(20)に代入することにより、ΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lが求められる。

【0076】このように算出したΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lが、製品として一定レベル以上の品質を保証できる成果物の数を増加させることを目的とした評価式Jを、最小にするための、カスケード熱電対に対する目標温度の補正值である。上述の例においては、評価式Jを最小にするΔCの各要素、ΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lを求めるために、偏微分によって作成した連立方程式を解く方法を順に説明したが、実際の作業では、連立方程式を解く必要はなく、干渉行列Mおよび調整前の8枚の熱電対付きウェーハの検出温度と目標温度との誤差P₀を取得し、その値を上記の式(20)に代入することによって、カスケード熱電対に対する目標温度の補正值を求めることができる。最後に、求められた補正值を使用して制御を行い、調整の結果を確認する。

【0077】図1および図2に示される構成において、各加熱ゾーン(U, CU, CL, Lゾーン)のカスケ

ド熱電対に対する目標温度に、それぞれ上記で算出した補正值、ΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lを加える。そして、この目標温度と、カスケード熱電対の検出温度が一致するように制御する。十分に時間が経過し、温度が安定したところで、8枚の熱電対付きウェーハの検出温度と、本来の目標温度との誤差を確認する。それぞれの誤差が許容範囲内であれば、調整は終了する。もしも、誤差が許容範囲を超えていた場合には、追加の調整を行う。追加の調整の手順は、上記の場合と同じであるが、その際、1回目の調整では、調整前の8枚の熱電対付きウェーハの検出温度と、目標温度との誤差を取得し、P₀としていた(式(3))が、追加の調整では、1回目の調整結果の確認における、8枚の熱電対付きウェーハの検出温度と、本来の目標温度との誤差をそれぞれ取得し、P₀として使用する。後は、上記と同様に、式(20)に代入して、ΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lを求めて、このΔT_U、ΔT_{CU}、ΔT_{CL}、ΔT_Lを、1回目の調整で補正した各加熱ゾーンのカスケード熱電対に対する目標温度にさらに加える。そして、この目標温度と、カスケード熱電対の検出温度が一致するように制御し、再調整の結果を確認する。通常は、1~2回、多くても3

回以内の調整で良好な結果を得ることができるが、それでも許容範囲を超える場合には、干渉行列の取得から再実行するのが好ましい。

【0078】以上に説明した温度制御方法、熱処理装置は、半導体製造装置における半導体製造方法として用いられる。例えば、拡散装置に適用された場合の拡散プロセスについては、以下のようなものがある。

①パイロジエニック酸化

水素ガスを酸素ガスにより燃焼させて水蒸気を生成し、その水蒸気を反応室に導入して、ウェーハまたはウェーハ上に堆積されている膜を酸化する。処理温度は700～1000℃であり、圧力は常圧で処理される。酸化速度を考慮すると、好適な処理温度としては800～1000℃である。

②ドライ酸化

酸素ガスを反応室内に導入して、ウェーハまたはウェーハ上に堆積されている膜を酸化する。処理温度は700～1000℃で常圧で処理される。酸化速度を考慮すると、好適な処理温度としては800～1000℃である。

③磷拡散

三塩化燐(POCl₃)、酸素ガス、及び窒素ガスをキャリアガスとして、反応室内に導入する。処理温度は800～1000℃で常圧で処理される。

④アニール処理

窒素ガスなどの不活性ガスを反応室内に導入し、処理温度は800～1100℃、圧力は常圧で処理される。

【0079】半導体装置において、上記プロセス①、②は、素子間の絶縁分離、電極あるいは配線の層間分離、MOSFETのゲート酸化膜、DRAMのメモリセル蓄電容量部、不純物拡散及びイオン注入のマスク、表面不活性化と保護などに広く用いられる。また上記プロセス③では、ゲート電極、配線のポリシリコン膜へのドーピング、抵抗体やコンタクト部へのドーピングなどに用いられる。また、上記プロセス④では、不純物層への不純物を結晶内部に移動させるのに用いられる。

【0080】実施の形態2。実施の形態1では、実プロセス前に補正值を求める場合について説明したが、実プロセス中に直接補正值を求めるようにしても良い。実施の形態2は、実プロセス前に干渉行列Mだけを求め、実プロセスである基板処理中に8枚の熱電対付きウェーハの検出温度と目標温度との誤差P₀を取得し、式(20)に代入することによって、カスケード熱電対に対する目標温度の補正值を求めて、この求められた補正值を目標温度に加えて温度制御することができる。

【0081】実施の形態3。実施の形態2では、熱電対付きウェーハにおいては、熱電対が基板処理中に露出することになるので、金属汚染が生じる虞がある。そこで、熱電対付きウェーハに替えて、炉内にプロファイル熱電対を挿入するようにしても良い。プロファイル熱電

対200は、例えば図3に示されるように、石英管またはSiC等のセラミック管201で熱電対を覆っている構造を有するので、熱電対204による金属汚染を低減することができる。セラミック管201の中には、複数(8本)の熱電対204が熱電対封入部202により封入され、その温度検出信号が配線203を介して得られる。各熱電対は実施の形態1に示した熱電対付きウェーハそれぞれに対応する位置(高さ位置)に設けられている。このプロファイル熱電対は、単管で構成され、比較的空間の狭い反応室内に挿入するのに適している。なお、更にこれを複数設けることにより、より多数の位置での温度検出も可能となる。

【0082】実施の形態4。また、実プロセスで検出温度と目標温度との誤差を検出する場合に、図4に示すような、ヒータ熱電対(ヒータ制御用熱電対)300として、カスケード熱電対304を8本設け、このカスケード熱電対の検出温度とその目標温度との差を誤差P₀として取得し、式(20)に代入することにより、目標温度の補正值を求め、この求められた補正值を目標温度に加えて温度制御するようにしても良い。なお、図4に示すヒータ制御用熱電対300は、カスケード熱電対304が封入された石英またはSiCのセラミック管301を熱電対封入部305に8本並設し、これを均熱管(図1の12)と反応管(図1の13)との間に湾曲させて挿入できるようにしたものである。このようなカスケード熱電対304は、別々にセラミック管301に封入されているので、カスケード熱電対304相互間の干渉を防止し得る。なお、このような干渉の恐れが無い場合は、一つのセラミック管に複数の熱電対を挿入するようにしても良い。

【0083】実施の形態5。以上に説明した実施の形態は、いずれも実プロセス前に干渉行列Mを求めるようにしたものであるが、基板処理時間が長く、また、干渉行列を求める際の多少の温度昇降をしても支障が生じない半導体装置等の加熱処理をする場合は、実プロセスである基板処理中に干渉行列を求める、更に誤差と補正值を求めて目標温度を補正するようにしても良い。

【0084】実施の形態6。以上に述べた実施の形態は加熱ゾーンが縦方向に分割される縦型装置について説明したが、一枚から数枚までのウェーハを処理し、加熱ゾーンがウェーハ面内方向に分割される枚葉装置にも本発明は適用できる。図5はこの枚葉装置を示すものであり、(a)は側面図、(b)は複数のゾーンを示す平面図である。この場合、熱電対付きウェーハによる温度検出に替えて放射温度計を用いると非接触で測定でき、金属汚染を防止することが容易となる。図5に示す枚葉装置は、処理室である反応管1aを有する加熱炉1にウェーハ(基板2)を載置するサセプタ4が設けられ、加熱炉1内を所定の温度に加熱しつつ反応ガスを供給して基板2上に薄膜を形成する。加熱源であるヒータ3は加熱

ゾーンとして①、②、③の3ゾーンを有し、各ゾーンからの熱は、主として熱容量のある基板2を支持するサセプタ4及び基板2、そしてガス管5より流入される反応ガスに吸収される。

【0085】制御用のセンサとしては、各加熱ゾーン(①②③)毎に2個の放射温度計(赤外線放射温度計:第2の温度検出器)6A~6F及びヒータモニタ用又はヒータ制御用として使用され、縦型装置のカスケード温度計に対応するヒータ熱電対7A~7Cが設けられている。温度調節器AD変換部8では、熱電対信号をAD変換し、温度調節器制御部9に温度デジタルデータを送信する。放射温度計6A~6Fも同様に、センサ信号をAD変換し、温度調節器制御部9に温度デジタルデータを送信する。温度調節器制御部9は、受け取った温度デジタルデータを用い、制御(PIDなど)演算を行い、ヒータパワー値(0~100%)を決定する。このPID制御において用いられる目標温度が既述の補正值により補正される構成となっている。なお、サイリスタ制御器410は、温度調節器制御部9からの電気信号(0~100%)を受け取り、サイリスタ点弧により、ヒータを加熱する。なお、温度調節器制御部9には、交流電源411を介してメインコントローラ412が接続されると共に温度調節器表示操作部413が接続されている。また、交流電源414が放射温度計6及び温度調節器制御部9に接続されている。

【0086】本実施の形態における放射温度計6A~6Fは、被測定物としてのサセプタ4の温度を正確に測定し、サセプタ4の温度を制御するために、反応管1a内に設置される。温度センサとして放射温度計が使われるには、非接触で測定でき、且つ応答性が良いためである。また、放射温度計を熱電対とすると、その測定原理から該熱電対をサセプタに取付ける必要があり、従ってこの場合には、サセプタ4を回転させることができなくなるからである。このように、枚葉装置は縦型装置とゾーン数が異なり、対応するヒータ熱電対(第1の温度検出器)及び放射温度計(第2の温度検出器)の数も適宜変更される。このような枚葉装置においても、本発明を適用することにより、ウェーハの面内方向への温度均一性を向上させることができる。なお、縦型装置において説明した熱電対付きウェーハにおいて、更に同一ウェーハ面内に複数の熱電対を設けることにより、縦型装置においても、面内方向への温度均一性を向上させることも可能である。

【0087】以上において、本発明による、被処理体の領域における温度制御方法の実施の形態について説明したが、これらの手順を実行することによって、熟練した作業者でなくとも、早く確実に、被処理体の領域における均熱調整を行うことができるものである。また、以上の手順をコンピュータによりプログラム化し、温度コントローラ等にソフトウェアとして組み込むことによっ

て、熟練作業者の介入を必要としない、被処理体の領域における自動均熱調整を行うことができる。例えば、上述のコンピュータ化により、図9で示したような結果をもたらすカスケード熱電対に対する目標温度の設定が自動的に可能となる。なお、上記の例では、8枚の熱電対付きウェーハを使用したが、もっと多くの熱電対付きウェーハを使用する方法、また最上部ウェーハから最下部ウェーハの横を上下に移動する機構をもつ熱電対を用いて、同様の手段を用いることにより、より広い領域をより細かい単位で、均一な温度範囲に調整することもできる。また、以上の例では、カスケード熱電対を制御に使用した場合を説明したが、カスケード熱電対を常時設置できない構造の場合には、ヒータ熱電対を代わりに使用して、同様に調整を行うこともできる。また、熱電対付きウェーハに代わり、放射温度計を用いることも可能である。

【0088】

【発明の効果】以上説明したように、本発明によれば、実際に温度制御を行う複数の領域に対する補正した目標温度をコンピュータを利用して自動的に設定することができあり、熟練した作業者がいなくとも、短時間かつ正確に最適の熱処理を行うことができる。

【図面の簡単な説明】

【図1】この発明の熱処理装置用均熱調整方法が適用された縦型拡散炉の実施の形態を示す構成図である。

【図2】図1によって示される縦型拡散炉の外壁の内部を示す拡大図である。

【図3】プロファイル熱電対の一例を示す図である。

【図4】カスケード熱電対の一例を示す図である。

【図5】枚葉装置を示す図であり、(a)は側面図、(b)は加熱ゾーンを示す平面図である。

【図6】熱処理装置の中の典型的な従来例の一つである縦型拡散炉を示す構成図である。

【図7】図6の縦型拡散炉に収納されたウェーハの加熱ゾーンに対応して熱電対付きウェーハを配置したところを示す図である。

【図8】図6の縦型拡散炉に収納されたウェーハの加熱ゾーンおよびその間のゾーンに対応して熱電対付きウェーハを配置したところを示す図である。

【図9】図7のように設定された熱処理装置において、カスケード熱電対の検出温度をウェーハ処理の目標温度に一致するように温度制御を行った場合の、カスケード熱電対と熱電対付きウェーハとの検出温度の関係を示す図である。

【図10】図9で示される状態を改良すべく、カスケード熱電対の検出温度が補正された目標温度に一致するように温度制御をした場合のカスケード熱電対と熱電対付きウェーハとの検出温度の関係を示す図である。

【図11】図10で示された状態において、ウェーハの加熱ゾーンに対応した位置以外の位置に熱電対付きウェ

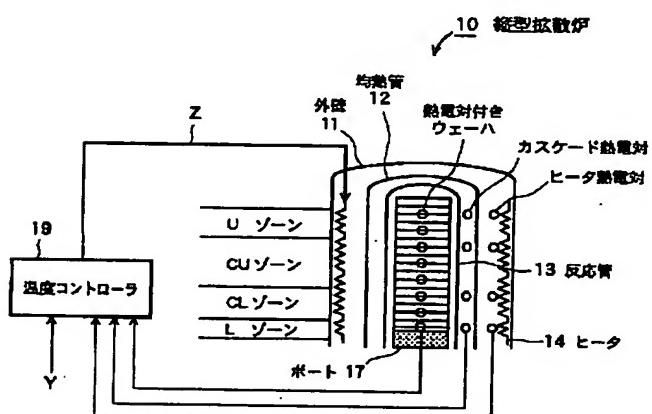
一ハを増加配置した場合の、カスケード熱電対と熱電対付きウェーハとの検出温度の関係を示す図である。

【図12】図11で示される状態を改良すべく、カスケード熱電対の検出温度を熟練作業者が選択した目標温度に一致するように温度制御をした場合のカスケード熱電対と熱電対付きウェーハとの検出温度の関係を示す図である。

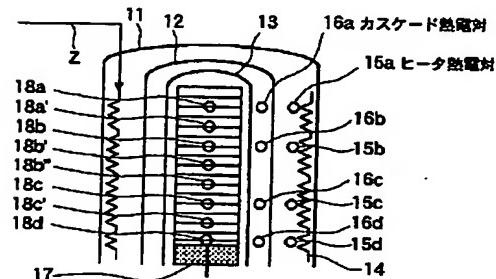
【符号の説明】

6 A～6 F 放射温度計、10 縦型拡散炉、11 外

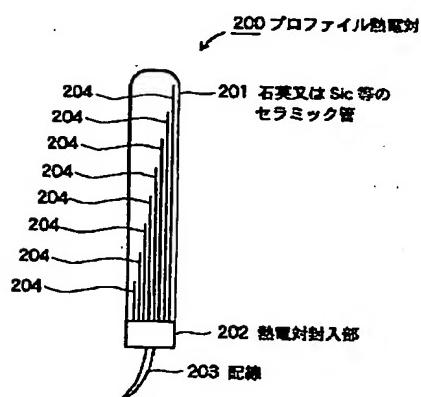
【図1】



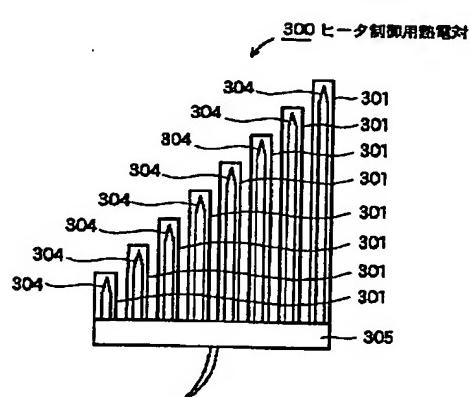
【図2】



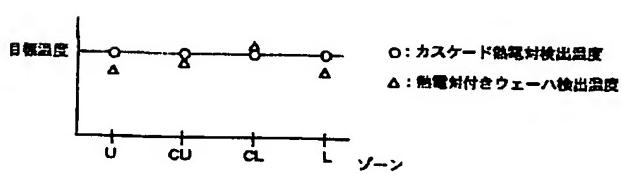
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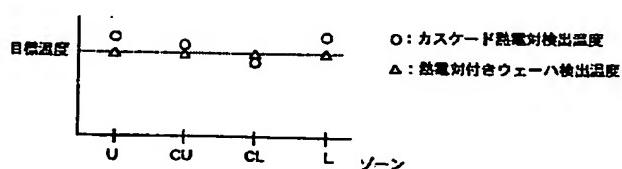
【図4】



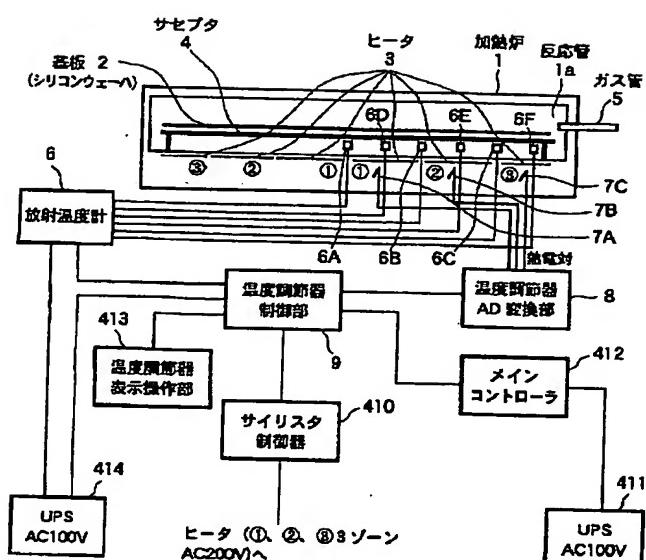
【図9】



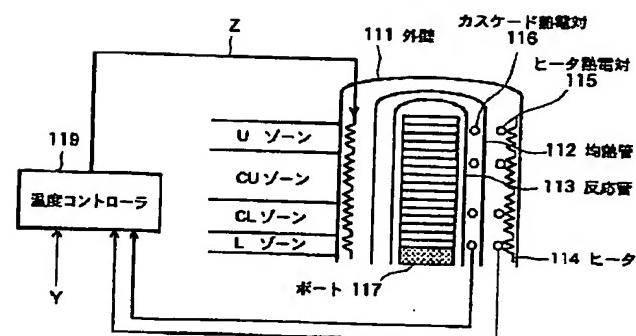
【図10】



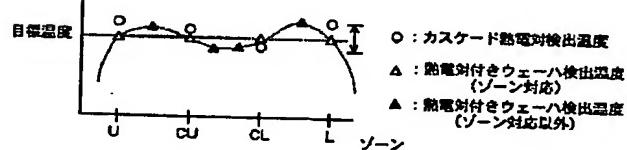
【図5】



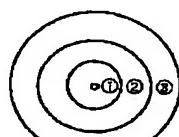
【図6】



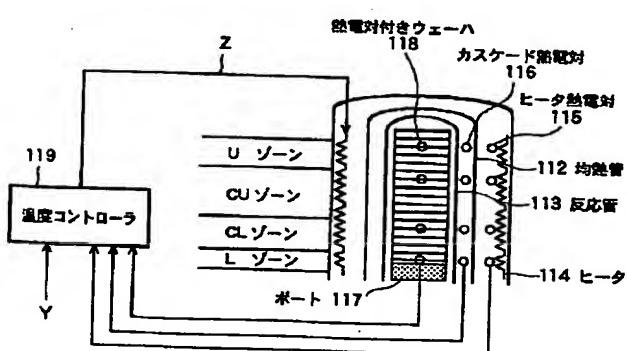
【図11】



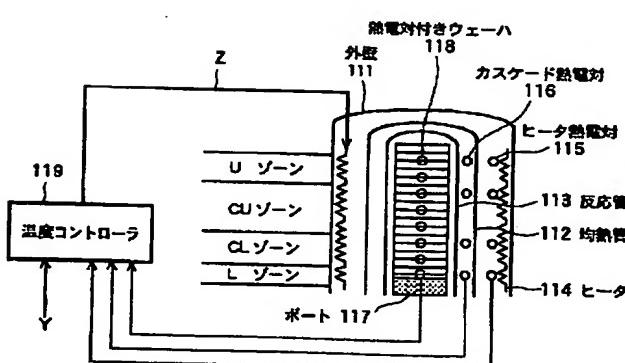
(b)



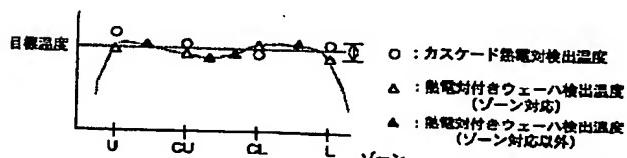
【図7】



【図8】



【図12】



フロントページの続き

(72) 発明者 中野 稔

東京都中野区東中野三丁目14番20号 株式
会社日立国際電気内

(72) 発明者 山口 英人

東京都中野区東中野三丁目14番20号 株式
会社日立国際電気内

F ターム (参考) 5H323 AA05 CA06 CB02 CB42 DB03

FF01 FF03 GG02 KK05 NN03

PP01

【公報種別】公開特許公報の訂正

【部門区分】第6部門第3区分

【発行日】平成14年10月4日(2002.10.4)

【公開番号】特開2002-175123 (P2002-175123A)

【公開日】平成14年6月21日(2002.6.21)

【年通号数】公開特許公報14-1752

【出願番号】特願2001-272218 (P2001-272218)

【訂正要旨】分類誤載につき下記の通り訂正する。

【記】

【国際特許分類第7版】

【誤】

G05D 23/19 G

H01L 21/22 501 N

511 Q

21/324 T

【正】

G05D 23/22 A

H01L 21/22 501 N

511 Q

21/324 T

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2002-175123
 (43)Date of publication of application : 21.06.2002

(51)Int.CI. G05D 23/22
 H01L 21/22
 H01L 21/324

(21)Application number : 2001-272218 (71)Applicant : HITACHI KOKUSAI ELECTRIC INC
 (22)Date of filing : 07.09.2001 (72)Inventor : TANAKA KAZUO
 UENO MASAAKI
 NAKANO MINORU
 YAMAGUCHI HIDETO

(30)Priority

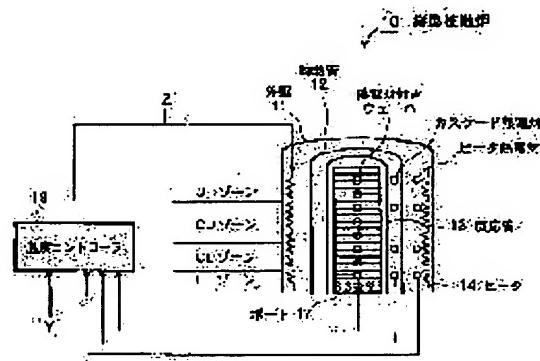
Priority number : 2000298858 Priority date : 29.09.2000 Priority country : JP

(54) TEMPERATURE CONTROL METHOD, HEAT TREATMENT DEVICE AND METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a temperature control method making it possible to perform accurate heat equalizing adjustments with little error in a short time over an entire wafer area to be heat treated at a desired temperature, even without a skilled operator, and also enabling automation using a computer system.

SOLUTION: The temperature control method is for controlling a heating device having at least two heating zones, so that the temperature detected at the wafer position attains the desired temperature. Temperatures are detected in positions more than the number of the heating zones and in at least one wafer position in each heating zone, and the heating device is controlled so that the desired temperature is within the range between the maximum and minimum values of the plurality of detected temperatures.



LEGAL STATUS

[Date of request for examination] 29.03.2005

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application]

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CLAIMS

[Claim(s)]

[Claim 1] As detection temperature in a predetermined location is made into the target temperature, it is the temperature control approach which controls the heating apparatus which has at least two heating zones. The temperature control approach which there are than the number of said heating zones, and detects the temperature in at least one predetermined location in each heating zone, and is characterized by controlling said heating apparatus so that said target temperature is included between the maximum of the detection temperature in two or more detected predetermined locations, and the minimum value. [more]

[Claim 2] In the temperature control approach according to claim 1, the 1st predetermined location corresponding to each zone is equipped with the 1st thermometric element. It is used for the temperature control approach which controls said heating apparatus to make detection temperature by said 1st thermometric element into the 1st target temperature. The 2nd predetermined location near [location / 1st / predetermined] a processed material is equipped with the 2nd thermometric element. When changing said 1st target temperature in said 1st thermometric element The interference matrix M which is a matrix of the multiplier which shows the degree from which the detection temperature of said 2nd thermometric element changes And the temperature control approach characterized by acquiring the difference P0 of the 2nd [in said 2nd thermometric element] target temperature, and the detection temperature by said 2nd thermometric element, and amending said 1st target temperature based on these interference matrix M and an error P0.

[Claim 3] The temperature control approach characterized by asking for new error P0' and amending said 1st amended target temperature further by performing temperature control using said 1st amended target temperature in the temperature control approach according to claim 2 using this error P0' and said interference matrix M.

[Claim 4] In order to detect whenever [by the processing room, the heating apparatus which heats the processed material which has at least one heating zone and was prepared in said processing interior of a room, and said heating apparatus / stoving temperature] in the 1st predetermined location, The 1st detection temperature which was equipped with the 1st thermometric element formed in each at least one zone, and was detected by said 1st thermometric element, In the temperature control approach which controls said heating apparatus based on the 1st target temperature about the 1st detection temperature this -- And it has two or more 2nd thermometric elements which detect whenever [by said heating apparatus / stoving temperature] in the 2nd predetermined location near [location / 1st / predetermined] said processed material than the number of said heating zones. the 2nd detection temperature detected by said 2nd thermometric element -- this -- the temperature control approach characterized by measuring the 2nd target temperature about the 2nd detection temperature, acquiring the correction value of said 1st target temperature, and for said correction value amending said 1st target temperature, and performing temperature control.

[Claim 5] It is the temperature control approach characterized by being carried out before the real process in which acquisition of said correction value actually processes a processed substrate in the temperature control approach according to claim 4.

[Claim 6] A processing room and the heating apparatus which has at least two heating zones by which temperature control is carried out so that detection temperature in a predetermined location may be made into the target temperature, Two or more thermometric elements which detect the temperature in at least one predetermined location [in / and / than the number of said heating zones / each heating zone], The thermal treatment equipment which comes to have the control unit which controls said heating apparatus so that said

target temperature may be included between the maximum of two or more detection temperature depended on said two or more thermometric elements, and the minimum value.

[Claim 7] The heating apparatus which has at least two heating zones is controlled to make detection temperature in a predetermined location into the target temperature. More [are the manufacture approach of a semiconductor device of heat-treating to a processed substrate, and / number / of said heating zones] And the manufacture approach of the semiconductor device characterized by controlling said heating apparatus so that the temperature in at least one predetermined location in each heating zone is detected and said target temperature is included between the maximums of detection temperature and the minimum values in two or more detected predetermined locations.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] In order that this invention may heat-treat a processed object especially about the manufacture approach of the temperature control approach in semiconductor fabrication machines and equipment etc., a thermal treatment equipment, and a semiconductor device Divide a thermal treatment equipment into two or more heating zones, about these two or more heating zones, actually set up target temperature, perform temperature control, and with the detection temperature in many processed object fields rather than said two or more heating zones It is related with the manufacture approach of the temperature control approach which amended said target temperature, a thermal treatment equipment, and a semiconductor device.

[0002]

[Description of the Prior Art] In the conventional thermal treatment equipment, when heat-treating a semiconductor wafer (substrate) as a processed object and performing membrane formation etc., various processing temperature corresponding to classification and its manufacture processes, such as membrane formation which is the processing result object, is required. Therefore, temperature control of the temperature of the processed object when heat-treating is carried out by approach (the soak adjustment approach) which is in agreement with this processing temperature as much as possible. Drawing 6 is drawing showing the structure of the vertical mold diffusion furnace which is typical one in such a thermal treatment equipment. The liner tube 112 and coil 113 with which the vertical mold diffusion furnace shown in drawing 6 was covered with the outer wall 111, The heater 114 for heating the inside of a coil 113, and the heater thermocouple 115 which detects the temperature of a heater 114, The cascade thermocouple 116 which detects the temperature between a liner tube 112 and a coil 113, It consists of a boat 117 carrying the wafer for heat-treating, and a temperature controller 119 which controls the control input Z to a heater 114 (power value) based on the detection temperature and the target temperature Y directed which the heater thermocouple 115 and the cascade thermocouple 116 detect.

[0003] The heater 114 is divided into two or more heating zones in order to control whenever [furnace temperature] (temperature of a coil 113) to high degree of accuracy more. Like drawing 6 In the division into four heating zones, corresponding to each heating zone called U, CU, CL, and L zone sequentially from the upper part (these names are used henceforth), the heater thermocouple 115 and the cascade thermocouple 116 are installed. Detecting the temperature of the heater thermocouple 115 so that it may be in agreement with the target temperature Y in the detection temperature of the cascade thermocouple 116, a temperature controller 119 computes the control input Z to a heater 114 according to the algorithms (PID operation etc.) which were able to be given beforehand, and is adjusting the power value to a heater 114.

[0004] Thus, although temperature control was performed so that it might be in agreement with the target temperature of wafer processing of the detection temperature in the cascade thermocouple 116 conventionally, quite a few errors are between the temperature in the location of the wafer which actually heat-treats, and the detection temperature of the cascade thermocouple corresponding to it, and this error may become the factor which reduces the quality of heat treatment. For this reason, it is required to control to become the temperature of a near field or the target temperature of wafer processing of the temperature of the wafer itself with a wafer, and to raise the quality of heat treatment. For that purpose, a means by which a wafer detects the temperature of a near field or the temperature of the wafer itself is needed. Although there are various kinds of things, such as the approach of inserting a thermocouple into a coil and measuring the temperature near the wafer as a detection

means and a method of presuming wafer temperature using a mathematical model, how to use the wafer for thermometries (wafer with a thermocouple) which equipped the wafer with the thermocouple directly is explained as those one example here.

[0005] Drawing 7 shows the example which used the above-mentioned wafer with a thermocouple. In this case, the wafer 118 with a thermocouple is arranged corresponding to each of U, CU, CL, and L zone which is four heating zones. Moreover, the heater thermocouple 115 and the cascade thermocouple 116 are also installed in the location corresponding to each of these U, CU and CLs, and L zone. The temperature detected with the wafer 118 with a thermocouple is incorporated by the temperature controller 119 like the heater thermocouple 115 and the cascade thermocouple 116. Although the location and number equipped with a thermocouple may incidentally change with operation in a wafer with a thermocouple, the wafer 118 with a thermocouple in the example described here shall have equipped only with one thermocouple in the center of a wafer.

[0006] One example of the relation of the detection temperature of the cascade thermocouple 116 and the wafer 118 with a thermocouple at the time of performing temperature control so that it may be in agreement with the target temperature of wafer processing of the detection temperature of the cascade thermocouple 116 with a configuration like drawing 7 is shown in drawing 9. In this case, although the detection temperature (O) of the cascade thermocouple 116 is in agreement with target temperature, the error has produced the detection temperature (delta) of the wafer 118 with a thermocouple between target temperature. Moreover, since size with error etc. differs for every heating zone, it becomes the factor which reduces the quality of heat treatment. In this case, there is the approach of using the error between the detection temperature of the wafer 118 with a thermocouple and the target temperature over the cascade thermocouple 116 as correction value over the target temperature of a cascade thermocouple. For example, in drawing 9, to target temperature, the detection temperature of the wafer with a thermocouple of U zone adds these 5 degrees C to the target temperature over the cascade thermocouple of U zone as correction value, in being low 5 degrees C.

[0007] By above-mentioned amendment, although the detection temperature of the cascade thermocouple 116 of U zone becomes higher 5 degrees C than original target temperature, it can make the detection temperature of the wafer with a thermocouple of U zone in agreement with original target temperature. Similarly, one example of the relation of the detection temperature of the cascade thermocouple at the time of amending and a wafer with a thermocouple is shown in drawing 10 to all heating zones. In this case, although the detection temperature (O) of the cascade thermocouple 116 stopped being in agreement with original target temperature, its detection temperature (delta) of the wafer 118 with a thermocouple corresponds with target temperature. The quality of heat treatment can be raised because the temperature of the actually heat-treated wafer was in agreement with target temperature. However, in the above-mentioned example, in order to make high 5 degrees C of detection temperature of the wafer 118 with a thermocouple, even if it adds 5 degrees C to the target temperature over a cascade thermocouple as correction value, 5 degrees C of detection temperature of a wafer with a thermocouple do not actually become high in many cases, and the repeat of several tuning is needed.

[0008] Furthermore, although the wafer 118 with a thermocouple is arranged in the configuration of drawing 7 in the location corresponding to the heater thermocouple 115 and the cascade thermocouple 116 which were installed for every heating zone, respectively. In order to measure the temperature of the other wafer, two or more wafers with a thermocouple are increased and arranged like drawing 8. It thinks, as one example of the relation of the detection temperature of the cascade thermocouple and the wafer with a thermocouple at the time of incorporating to a temperature controller 119 shows the temperature detected by them similarly to drawing 11. In this case, although the detection temperature (delta) of the wafer 118 with a thermocouple arranged in the location representing each heating zone is in agreement with target temperature, the detection temperature (**) of the wafer with a thermocouple arranged in the other location has produced the error to target temperature. Now, a difference appears in the quality of heat treatment and it becomes the cause that the manufacture rate of a result object that the quality more than fixed level can be guaranteed as a product falls. As this cure, if possible, the temperature gradient of a wafer field is abolished, and there is the approach of amending the target temperature over the cascade thermocouple 116 further so that it may be made homogeneity.

[0009] For example, to target temperature, the detection temperature of the wafer [as / in drawing 11] with a thermocouple installed between CL zone and L zone decreases as correction value from the target temperature over the cascade thermocouple of about 1 degree C, CL zone, and L zone, when high 3 degrees C. In this case,

it is because the purpose that an error becomes large to target temperature and the detection temperature of the wafer with a thermocouple corresponding to a heating zone abolishes the temperature gradient of a wafer field as a result shortly cannot be attained if having considered as about 1 degree C, without making correction value into 3 degrees C uses 3 degrees C of an error as correction value of the target temperature over a cascade thermocouple like previously. Furthermore, since it is influenced of the amendment of CL zone and L zone through which it passes, respectively and the detection temperature of the wafer with a thermocouple which having made correction value into about 1 degree C installed between CL zone and L zone needs to adjust correction value several times when information, such as a degree of interference between heating zones, is indefinite, it is semantics which makes the initial value about 1 degree C first.

[0010] As shown in drawing 8, when it constitutes, one example of the relation of the detection temperature of the cascade thermocouple and the wafer with a thermocouple at the time of being adjusted so that the detection temperature of all wafers with a thermocouple may make the error over target temperature small (for example, a skillful operator adjusting) is shown in drawing 12. In this case, although the detection temperature (delta) of the wafer with a thermocouple corresponding to a heating zone stopped being in agreement with target temperature a little, the error with the target temperature in all wafers with a thermocouple (**, **) is decreasing as a whole compared with the case of drawing 11 (the width of face of dispersion shown by the arrow head is small). Thereby, the result significant work which can guarantee the quality more than fixed level as a product can be made to increase. However, like drawing 12, existence of the operator who became skillful in order to, have made small the error with the target temperature in a wafer with a thermocouple on the whole is required, and in order that a skillful operator may also adjust repeatedly, the present condition is needing much adjustment time amount.

[0011]

[Problem(s) to be Solved by the Invention] The above-mentioned conventional soak adjustment approach for thermal treatment equipments divides the wafer field of a thermal treatment equipment into two or more heating zones, and is related with all heating zones. Temperature detection equipments, such as a cascade thermocouple around a furnace, detect the temperature of the field which actually sets up target temperature and performs temperature control, and although it is going to carry out heating control so that the processed object arranged in a furnace may be processed at target temperature with the detected temperature Since it is dependent on experience and trial of a skillful operator, the decision of the laying temperature to temperature detection equipment has a limit to a staff with the corresponding capacity, and has the problem that the setup time is also seriously needed.

[0012] It aims at offering the manufacture approach of the temperature control approach which it crosses to the all field of a processed material even if it is made that this invention should solve the above-mentioned problem and there is not a skillful operator, and is a short time simply, and can make an error small, can adjust to target temperature (soak adjustment), and can also perform automation easily according to a computer system, a thermal treatment equipment, and a semiconductor device.

[0013]

[Means for Solving the Problem] In order to solve the technical problem mentioned above, the temperature control approach concerning this invention As detection temperature in a predetermined location is made into the target temperature, it is the temperature control approach which controls the heating apparatus which has at least two heating zones. And in each heating zone, the temperature in at least one predetermined location is detected, and it is characterized by controlling said heating apparatus so that said target temperature is included between the maximum of the detection temperature in two or more detected predetermined locations, and the minimum value than the number of said heating zones.

[0014] According to such a configuration, even if there is not a skillful operator, it can cross to all the fields of a processed material, and it is a short time simply, and an error can be made small and it can adjust to target temperature (soak adjustment). This invention is easily applicable to a vertical mold CVD system, sheet equipment, etc. with which it has two or more heating zones, and the temperature in two or more wafer locations with a thermocouple may be detected.

[0015] Moreover, in the temperature control approach of this invention, the 1st predetermined location corresponding to each zone is equipped with the 1st thermometric element. It is used for the temperature control approach which controls said heating apparatus to make detection temperature by said 1st thermometric element

into the 1st target temperature. The 2nd predetermined location near [location / 1st / predetermined] a processed material is equipped with the 2nd thermometric element. When changing said 1st target temperature in said 1st thermometric element The interference matrix M which is a matrix of the multiplier which shows the degree from which the detection temperature of said 2nd thermometric element changes And the difference P0 of the 2nd [in said 2nd thermometric element] target temperature and the detection temperature by said 2nd thermometric element is acquired, and it is characterized by amending said 1st target temperature based on these interference matrix M and an error P0.

[0016] According to such a configuration, even if there is not a skillful operator, it is a short time simply, and an error can be made small, it can adjust [it can cross to all the fields of a processed material, and] to target temperature (soak adjustment), and a computer system can also perform automation easily. In addition, in the gestalt of operation, a cascade thermocouple is equivalent to the 1st thermometric element, and the thermocouple attached to the wafer (wafer with a thermocouple) is equivalent to the 2nd thermometric element. And according to this configuration, temperature control is made based on the interference matrix M and error P0 which were acquired once, the target temperature of a cascade thermocouple being amended.

[0017] Moreover, the temperature control approach of this invention is performing temperature control using said 1st amended target temperature, asks for new error P0', and is characterized by amending said 1st amended target temperature further using this error P0' and said interference matrix M.

[0018] According to such a configuration, temperature control can be performed with a more sufficient precision and a processed material can be heated with a more sufficient precision to request temperature.

[0019] Moreover, in order that the temperature control approach of this invention may detect whenever [by the processing room, the heating apparatus which heats the processed material which has at least one heating zone and was prepared in said processing interior of a room, and said heating apparatus / stoving temperature] in the 1st predetermined location, The 1st detection temperature which was equipped with the 1st thermometric element formed in each at least one zone, and was detected by said 1st thermometric element, In the temperature control approach which controls said heating apparatus based on the 1st target temperature about the 1st detection temperature this -- And it has two or more 2nd thermometric elements which detect whenever [by said heating apparatus / stoving temperature] in the 2nd predetermined location near [location / 1st / predetermined] a processed material than the number of said heating zones. the 2nd detection temperature detected by said 2nd thermometric element -- this -- it is characterized by measuring the 2nd target temperature about the 2nd detection temperature, acquiring the correction value of said 1st target temperature, and for said correction value amending said 1st target temperature, and performing temperature control.

[0020] Moreover, in the temperature control approach of this invention, acquisition of said correction value is characterized by being carried out before the real process which actually processes a processed substrate.

[0021] According to such a configuration, there is no need of forming the 2nd thermometric element into a real process, and the bad influence to the processed material by forming a thermometric element can be lost.

[0022] Moreover, the heating apparatus which has at least two heating zones by which temperature control is carried out so that the thermal treatment equipment concerning this invention may make a processing room and detection temperature in a predetermined location the target temperature, Two or more thermometric elements which detect the temperature in at least one predetermined location [in / and / than the number of said heating zones / each heating zone], It comes to have the control unit which controls said heating apparatus so that said target temperature may be included between the maximum of two or more detection temperature depended on said two or more thermometric elements, and the minimum value.

[0023] According to such a configuration, even if there is not a skillful operator, it crosses to all the fields of a processed material, and the thermal treatment equipment which is a short time simply, and can make an error small and can be adjusted to target temperature (soak adjustment) can be offered.

[0024] Moreover, the manufacture approach of the semiconductor device concerning this invention The heating apparatus which has at least two heating zones is controlled to make detection temperature in a predetermined location into the target temperature. More [are the manufacture approach of a semiconductor device of heat-treating to a processed substrate, and / number / of said heating zones] And it is characterized by controlling said heating apparatus so that the temperature in at least one predetermined location in each heating zone is detected and said target temperature is included between the maximums of detection temperature and the minimum values in two or more detected predetermined locations.

[0025] According to such a configuration, even if there is not a skillful operator, it crosses to all the fields of a processed material, and the manufacture approach of the semiconductor device which is a short time simply, and can make an error small and can be adjusted to target temperature (soak adjustment) can be offered.

[0026]

[Embodiment of the Invention] Hereafter, the gestalt of implementation of this invention is explained based on an accompanying drawing. The most fundamental gestalt of this invention so that detection temperature in a predetermined location may be made into the target temperature In the temperature control approach which controls the heating apparatus which has at least one heating zone Although it is controlling said heating apparatus as the temperature in more predetermined locations of two or more than the number of said heating zones is detected and said target temperature is included between the maximum of two or more detected detection temperature, and the minimum value In the gestalt of the operation explained below, the gestalt in the case of performing temperature control so that the average of the difference of further two or more detection temperature and target temperature may serve as min is explained by considering this as a basic configuration.

[0027] The block diagram showing the vertical mold diffusion furnace whose gestalt 1. drawing 1 of operation is the gestalt of operation of the thermal treatment equipment with which the temperature control approach of this invention was applied, and drawing 2 are the enlarged drawings showing the interior of the outer wall of the vertical mold diffusion furnace of drawing 1. The liner tube 12 and coil 13 with which the vertical mold diffusion furnace 10 shown in drawing 1 and drawing 2 has been arranged in an outer wall 11, The heater 14 for heating the inside of a furnace, and the heater thermocouples 15a, 15b, 15c, and 15d which detect the temperature of a heater 14, The cascade thermocouples 16a, 16b, 16c, and 16d which detect the temperature between a liner tube 12 and a coil 13, a wafer -- temperature (temperature of the field where the wafer and the wafer have been arranged) -- detecting -- a sake -- a thermocouple -- with -- a wafer -- 18 -- a -- 18 -- a -- ' -- 18 -- b -- 18 -- b -- ' -- 18 -- b -- " -- 18 -- c -- 18 -- c -- ' -- 18 -- d -- containing -- plurality -- a wafer -- having carried -- a boat -- 17 -- It consists of temperature controllers 19 which calculate the control input Z from the heater thermocouples 15a, 15b, 15c, and 15d and cascade thermocouples [16a, 16b, 16c, and 16d] detection temperature and the target temperature Y to a heater 14 (power value). in addition -- the above -- a configuration -- setting -- a cascade -- a thermocouple -- 16 -- a -- 16 -- b -- 16 -- c -- 16 -- d -- this invention -- the -- one -- a thermometric element -- constituting -- a thermocouple -- with -- a wafer -- 18 -- a -- 18 -- a -- ' -- 18 -- b -- 18 -- b -- ' -- 18 -- b -- " -- 18 -- c -- 18 -- c -- ' -- 18 -- d -- it can set -- a thermocouple -- this invention -- the -- two -- a thermometric element -- constituting -- ***.

[0028] In the above-mentioned example, in order to control the temperature of the wafer field in a furnace with high precision, the inside of a furnace is divided into U, CU, CL, and L zone sequentially from four heating zones, i.e., the upper part. In each zone, impression of high-frequency power is enabled among those heater terminals that are not illustrated, and the seal of approval of the RF electric energy can be changed and carried out for every zone. Temperature control is possible for every zone by this, and it is possible to cover all zones, to attach homogeneity or the temperature gradient for which it asks, and to carry out a temperature control. And corresponding to each of these U, CU and CLs, and L zone, the heater thermocouples 15a, 15b, 15c, and 15d and the cascade thermocouples 16a, 16b, 16c, and 16d are installed, respectively. Moreover, a wafer with a thermocouple is arranged between every (18a, 18b, 18c, 18d) one-sheet U and CU zones and between CL and L zone, and two sheets [a total of eight] are arranged between every one-sheet CU and CL zones at the location which represents these U, CU and CLs, and L zone among the wafers carried in the boat 17, respectively.

[0029] In the soak adjustment approach of the wafer field in this vertical mold diffusion furnace 10, it is carried out from acquiring the correction value of the target temperature in the temperature control first performed on the occasion of product manufacture as pre-preparation which actually manufactures a product (semiconductor device). The correction value of this target temperature is used to the target temperature of the detection temperature of a cascade thermocouple, in order to make temperature of a wafer field into soak. That is, in the temperature control performed on the occasion of actual product manufacture, the wafer for the usual products is arranged in the location of a wafer with a thermocouple, and temperature detection of the wafer itself cannot be performed. Then, a temperature controller 19 can perform temperature control which makes temperature of a wafer field soak by performing temperature control which applied the above-mentioned correction value to the target temperature of cascade thermocouples [which are always arranged / 16a 16b, 16c, and 16d] detection temperature. Of course, if it is the configuration which can carry out the firm measurement of the temperature of

a wafer field by a certain approach, it cannot be overemphasized that controllability ability can be raised by controlling it instead of a cascade thermocouple.

[0030] Next, the principle of the soak adjustment approach for the wafer field of the vertical mold diffusion furnace 10 is explained in order. first -- control -- using it -- a cascade -- a thermocouple -- 16 -- a -- 16 -- b -- 16 -- c -- 16 -- d -- detection -- temperature -- soak -- adjustment -- the purpose -- it is -- a wafer -- a field -- temperature -- detecting -- a sake -- arranging -- having had -- a thermocouple -- with -- a wafer -- 18 -- a -- 18 -- a -- ' -- 18 -- b -- 18 -- b -- ' -- 18 -- b -- " -- 18 -- c -- 18 -- c -- ' -- 18 -- d -- detection -- temperature -- relation -- grasping -- things -- being required . In the above-mentioned vertical mold diffusion furnace 10, the detection temperature of eight wafers with a thermocouple receives the effect from a heater 14 by which temperature detection is carried out in the heater thermocouples 15a, 15b, 15c, and 15d corresponding to U, CU, CL, and L zone which are four heating zones. The degree of the effect is evaluated by approach which is described below.

[0031] First, it controls in agreement with the target temperature of wafer processing of cascade thermocouples [corresponding to U CU, CL, and L zone which are four heating zones / 16a 16b, 16c, and 16d] detection temperature. Although it does not need to be strictly the same as target temperature at this time, a temperature change needs to evaluate an effect degree by the temperature zone which is not greatly separated from the corresponding target temperature, in order to show the property which usually changes with temperature zones which control. After the temperature of all zones is stabilized, several degrees C (for example, 10 degrees C) are added to the target temperature over the cascade thermocouple of one zone, for example, U zone. Then, time amount fully passes and the variation (forward and when temperature rises, and it descends, it treats as a negative number) of the detection temperature of the wafer with a thermocouple which is eight sheets when temperature is stabilized is recorded. If variation added to the target temperature over the cascade thermocouple of U zone is set to deltaTU from this result and variation of the detection temperature of eight wafers with a thermocouple at that time is set to delta PU1-delta PU8 from the upper part at order, it can express as follows.

Namely, [0032] $\Delta P_{U1} = \alpha_{U1} \times \Delta T_U$, $\Delta P_{U2} = \alpha_{U2} \times \Delta T_U$... = =

$\Delta P_{U8} = \alpha_{U8} \times \Delta T_U$ [0033] In an above-mentioned case, change of the target temperature over the cascade thermocouple of U zone is the multiplier which shows the degree of the effect which it has on the detection temperature of eight wafers with a thermocouple, and α_{U1} to α_{U8} expresses that effect is so large that a numeric value is large. If similarly variation added to the target temperature over the cascade thermocouple of CU zone is set to deltaTCU and variation of the detection temperature of eight wafers 18 with a thermocouple at that time is set to delta PCU1-delta PCU8 from the upper part at order, it can express as follows. Namely, [0034] $\Delta P_{CU1} = \alpha_{CU1} \times \Delta T_{CU}$, $\Delta P_{CU2} = \alpha_{CU2} \times \Delta T_{CU}$... = =

$\Delta P_{CU8} = \alpha_{CU8} \times \Delta T_{CU}$ [0035] Moreover, about CL zone, it is

$\Delta P_{CL1} = \alpha_{CL1} \times \Delta T_{CL}$, $\Delta P_{CL2} = \alpha_{CL2} \times \Delta T_{CL}$... It is = It is =.... It is

$\Delta P_{CL8} = \alpha_{CL8} \times \Delta T_{CL}$ [0036]. Furthermore, about L zone, it is

$\Delta P_{L1} = \alpha_{L1} \times \Delta T_{L1}$, $\Delta P_{L2} = \alpha_{L2} \times \Delta T_{L2}$... It is = It is =.... It can express

$\Delta P_{L8} = \alpha_{L8} \times \Delta T_{L8}$.

[0037] It is [0038] when variation of the detection temperature of eight wafers with a thermocouple is set to delta P1-delta P8 from an above-mentioned result.

[Equation 1]

$$\Delta P_1 = (\alpha_{U1} \times \Delta T_U) + (\alpha_{CU1} \times \Delta T_{CU}) + (\alpha_{CL1} \times \Delta T_{CL}) + (\alpha_{L1} \times \Delta T_L)$$

⋮

$$\Delta P_8 = (\alpha_{U8} \times \Delta T_U) + (\alpha_{CU8} \times \Delta T_{CU}) + (\alpha_{CL8} \times \Delta T_{CL}) + (\alpha_{L8} \times \Delta T_L)$$

[0039] Although the variation of the detection temperature of a next door and eight wafers with a thermocouple acted as multiplier Bai of the change of the target temperature over the cascade thermocouple of each zone, it can be expressed with the sum. Therefore, in order to make it change so that the detection temperature of eight wafers with a thermocouple may be brought close to target temperature, it is necessary to use the above-mentioned relational expression and to determine the correction value to the target temperature over the cascade thermocouple of each zone. If a determinant expresses the above-mentioned relational expression, it will become like a degree type (1).

[0040]

[Equation 2]

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta P_5 \\ \Delta P_6 \\ \Delta P_7 \\ \Delta P_8 \end{bmatrix} = \begin{bmatrix} \alpha_{v1} & \alpha_{cv1} & \alpha_{cl1} & \alpha_{l1} \\ \alpha_{v2} & \alpha_{cv2} & \alpha_{cl2} & \alpha_{l2} \\ \alpha_{v3} & \alpha_{cv3} & \alpha_{cl3} & \alpha_{l3} \\ \alpha_{v4} & \alpha_{cv4} & \alpha_{cl4} & \alpha_{l4} \\ \alpha_{v5} & \alpha_{cv5} & \alpha_{cl5} & \alpha_{l5} \\ \alpha_{v6} & \alpha_{cv6} & \alpha_{cl6} & \alpha_{l6} \\ \alpha_{v7} & \alpha_{cv7} & \alpha_{cl7} & \alpha_{l7} \\ \alpha_{v8} & \alpha_{cv8} & \alpha_{cl8} & \alpha_{l8} \end{bmatrix} \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} \quad \dots \dots (1)$$

[0041] It sets at an above-mentioned ceremony (1), and is an interference matrix (change of the target temperature over a cascade thermocouple) about the matrix of the 1st term of the right-hand side. The matrix and call of a multiplier which show the degree of the effect which it has on the detection temperature of a wafer with a thermocouple, When it is referred to as M, the column vector (variation of target temperature to a cascade thermocouple) of the 2nd term of the right-hand side is set to deltaC and the column vector (variation of the detection temperature of a wafer with a thermocouple) of left part is expressed as deltaP, the above-mentioned formula (1) is [0042]. $\Delta P = M \Delta C$ (2)

[0043] It becomes. Thus, it can evaluate about the relation of the detection temperature of the cascade thermocouple used for control, and the wafer with a thermocouple which is the purpose. However, since this numeric value may include the error according to various factors, when it is necessary to raise precision more, or when allowances are in adjustment time amount, it cannot be overemphasized that creation of the above-mentioned interference matrix may be performed several times, and that average may be used.

[0044] Next, before actually adjusting, the error of the detection temperature of each wafer with a thermocouple at the time of controlling the detection temperature of a cascade thermocouple in agreement with the target temperature of wafer processing and target temperature is acquired. At this time, when the detection temperature of each wafer with a thermocouple is higher than target temperature, an error is made into a positive number, and in being lower than target temperature, it treats an error as a negative number. The error of the detection temperature of eight wafers with a thermocouple and target temperature can be set to E1-E8 from a upside heating zone at order, and can be expressed as a column vector P0 like the following formula (3).

[0045]

[Equation 3]

$$P_0 = \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{bmatrix} \quad \dots \dots (3)$$

[0046] next -- actually -- eight -- a sheet -- a thermocouple -- with -- a wafer -- 18 -- a -- 18 -- a -- ' -- 18 -- b -- 18 -- b -- ' -- 18 -- b -- " -- 18 -- c -- 18 -- c -- ' -- 18 -- d -- depending -- detection -- temperature -- a target -- temperature -- bringing close -- a sake -- adjustment -- carrying out . In case it adjusts, a valuation basis for the detection temperature of eight wafers with a thermocouple which are the purposes to evaluate which approached target temperature is needed. Then, the sum of the square of the error of the detection temperature of each wafer with a thermocouple and target temperature is made into a valuation plan, and it adjusts so that this may serve as min, so that the error over target temperature may become min in all the eight wafers with a thermocouple for the purpose of making the result significant work which can guarantee the quality more than fixed level as a product increase. Also when adjusting so that the sum of other valuation bases, for example, an absolute value with error, may be made into min, the approach to be described from now on can be applied. It is [0047] when the valuation plan mentioned above is shown. $J = |P_0 + \Delta P|^2$ (4)

[0048] It becomes. The contents of the right-hand side in this valuation plan J express the sum of deltaP which is the variation of the detection temperature of P0 which is the error of the detection temperature of eight wafers

with a thermocouple before adjustment, and target temperature, and eight wafers with a thermocouple which change with adjustments, and express the error of the detection temperature of eight wafers with a thermocouple after adjustment, and target temperature. It is [0049] when the formula (2) of point ** is applied to the above-mentioned valuation plan J (formula (4)).

$$J = |P_0 + [M \times \Delta C]|^2 \dots (5)$$

[0050] It is [0051] when a next door and the transpose of a matrix are used.

$$J = [P_0 + [M \times \Delta C]]^T \times [P_0 + [M \times \Delta C]]$$

.... (6)

[0052] It becomes ("T" expresses the transpose of a matrix). Furthermore, if the formula (1) and formula (3) of point ** are used, it will become like the following formula (7).

[0053]

[Equation 4]

$J =$

$$\begin{aligned} & \left[\begin{array}{c|cccc} E_1 & \alpha_{u1} & \alpha_{cu1} & \alpha_{cl1} & \alpha_{l1} \\ E_2 & \alpha_{u2} & \alpha_{cu2} & \alpha_{cl2} & \alpha_{l2} \\ E_3 & \alpha_{u3} & \alpha_{cu3} & \alpha_{cl3} & \alpha_{l3} \\ E_4 & \alpha_{u4} & \alpha_{cu4} & \alpha_{cl4} & \alpha_{l4} \\ E_5 & \alpha_{u5} & \alpha_{cu5} & \alpha_{cl5} & \alpha_{l5} \\ E_6 & \alpha_{u6} & \alpha_{cu6} & \alpha_{cl6} & \alpha_{l6} \\ E_7 & \alpha_{u7} & \alpha_{cu7} & \alpha_{cl7} & \alpha_{l7} \\ E_8 & \alpha_{u8} & \alpha_{cu8} & \alpha_{cl8} & \alpha_{l8} \end{array} \right] \times \left[\begin{array}{c} \Delta T_u \\ \Delta T_{cu} \\ \Delta T_{cl} \\ \Delta T_l \end{array} \right] \times \left[\begin{array}{c|cccc} E_1 & \alpha_{u1} & \alpha_{cu1} & \alpha_{cl1} & \alpha_{l1} \\ E_2 & \alpha_{u2} & \alpha_{cu2} & \alpha_{cl2} & \alpha_{l2} \\ E_3 & \alpha_{u3} & \alpha_{cu3} & \alpha_{cl3} & \alpha_{l3} \\ E_4 & \alpha_{u4} & \alpha_{cu4} & \alpha_{cl4} & \alpha_{l4} \\ E_5 & \alpha_{u5} & \alpha_{cu5} & \alpha_{cl5} & \alpha_{l5} \\ E_6 & \alpha_{u6} & \alpha_{cu6} & \alpha_{cl6} & \alpha_{l6} \\ E_7 & \alpha_{u7} & \alpha_{cu7} & \alpha_{cl7} & \alpha_{l7} \\ E_8 & \alpha_{u8} & \alpha_{cu8} & \alpha_{cl8} & \alpha_{l8} \end{array} \right] \times \left[\begin{array}{c} \Delta T_u \\ \Delta T_{cu} \\ \Delta T_{cl} \\ \Delta T_l \end{array} \right] \\ & - \left(E_1 + \alpha_{u1} \times \Delta T_u + \alpha_{cu1} \times \Delta T_{cu} + \alpha_{cl1} \times \Delta T_{cl} + \alpha_{l1} \times \Delta T_l \right)^2 \\ & - \left(E_2 + \alpha_{u2} \times \Delta T_u + \alpha_{cu2} \times \Delta T_{cu} + \alpha_{cl2} \times \Delta T_{cl} + \alpha_{l2} \times \Delta T_l \right)^2 \\ & - \left(E_3 + \alpha_{u3} \times \Delta T_u + \alpha_{cu3} \times \Delta T_{cu} + \alpha_{cl3} \times \Delta T_{cl} + \alpha_{l3} \times \Delta T_l \right)^2 \\ & - \left(E_4 + \alpha_{u4} \times \Delta T_u + \alpha_{cu4} \times \Delta T_{cu} + \alpha_{cl4} \times \Delta T_{cl} + \alpha_{l4} \times \Delta T_l \right)^2 \\ & - \left(E_5 + \alpha_{u5} \times \Delta T_u + \alpha_{cu5} \times \Delta T_{cu} + \alpha_{cl5} \times \Delta T_{cl} + \alpha_{l5} \times \Delta T_l \right)^2 \\ & - \left(E_6 + \alpha_{u6} \times \Delta T_u + \alpha_{cu6} \times \Delta T_{cu} + \alpha_{cl6} \times \Delta T_{cl} + \alpha_{l6} \times \Delta T_l \right)^2 \\ & - \left(E_7 + \alpha_{u7} \times \Delta T_u + \alpha_{cu7} \times \Delta T_{cu} + \alpha_{cl7} \times \Delta T_{cl} + \alpha_{l7} \times \Delta T_l \right)^2 \\ & - \left(E_8 + \alpha_{u8} \times \Delta T_u + \alpha_{cu8} \times \Delta T_{cu} + \alpha_{cl8} \times \Delta T_{cl} + \alpha_{l8} \times \Delta T_l \right)^2 \\ & - \left(E_1 + \alpha_{u1} \times \Delta T_u + \alpha_{cu1} \times \Delta T_{cu} + \alpha_{cl1} \times \Delta T_{cl} + \alpha_{l1} \times \Delta T_l \right)^2 \\ & - \left(E_2 + \alpha_{u2} \times \Delta T_u + \alpha_{cu2} \times \Delta T_{cu} + \alpha_{cl2} \times \Delta T_{cl} + \alpha_{l2} \times \Delta T_l \right)^2 \\ & - \left(E_3 + \alpha_{u3} \times \Delta T_u + \alpha_{cu3} \times \Delta T_{cu} + \alpha_{cl3} \times \Delta T_{cl} + \alpha_{l3} \times \Delta T_l \right)^2 \\ & - \left(E_4 + \alpha_{u4} \times \Delta T_u + \alpha_{cu4} \times \Delta T_{cu} + \alpha_{cl4} \times \Delta T_{cl} + \alpha_{l4} \times \Delta T_l \right)^2 \\ & - \left(E_5 + \alpha_{u5} \times \Delta T_u + \alpha_{cu5} \times \Delta T_{cu} + \alpha_{cl5} \times \Delta T_{cl} + \alpha_{l5} \times \Delta T_l \right)^2 \\ & - \left(E_6 + \alpha_{u6} \times \Delta T_u + \alpha_{cu6} \times \Delta T_{cu} + \alpha_{cl6} \times \Delta T_{cl} + \alpha_{l6} \times \Delta T_l \right)^2 \\ & - \left(E_7 + \alpha_{u7} \times \Delta T_u + \alpha_{cu7} \times \Delta T_{cu} + \alpha_{cl7} \times \Delta T_{cl} + \alpha_{l7} \times \Delta T_l \right)^2 \\ & - \left(E_8 + \alpha_{u8} \times \Delta T_u + \alpha_{cu8} \times \Delta T_{cu} + \alpha_{cl8} \times \Delta T_{cl} + \alpha_{l8} \times \Delta T_l \right)^2 \dots (7) \end{aligned}$$

[0054] Next, in order to ask for each elements delta TU, delta TCU, delta TCL, and delta TL of deltaC that a valuation plan J should be made min, the partial differential of the valuation plan J is carried out about each elements delta TU, delta TCU, delta TCL, and delta TL of deltaC. First, if the partial differential of the valuation plan J is carried out about deltaTU, it will become a degree type (8).

[0055]

[Equation 5]

$$\begin{aligned}
 & \frac{\partial J}{\partial \Delta T_U} \\
 = & ((2 \times \alpha_{U_1}) \times (E_1 + (\alpha_{U_1} \times \Delta T_U) + (\alpha_{CU_1} \times \Delta T_{CU}) + (\alpha_{CL_1} \times \Delta T_{CL}) + (\alpha_{TL_1} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_2}) \times (E_2 + (\alpha_{U_2} \times \Delta T_U) + (\alpha_{CU_2} \times \Delta T_{CU}) + (\alpha_{CL_2} \times \Delta T_{CL}) + (\alpha_{TL_2} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_3}) \times (E_3 + (\alpha_{U_3} \times \Delta T_U) + (\alpha_{CU_3} \times \Delta T_{CU}) + (\alpha_{CL_3} \times \Delta T_{CL}) + (\alpha_{TL_3} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_4}) \times (E_4 + (\alpha_{U_4} \times \Delta T_U) + (\alpha_{CU_4} \times \Delta T_{CU}) + (\alpha_{CL_4} \times \Delta T_{CL}) + (\alpha_{TL_4} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_5}) \times (E_5 + (\alpha_{U_5} \times \Delta T_U) + (\alpha_{CU_5} \times \Delta T_{CU}) + (\alpha_{CL_5} \times \Delta T_{CL}) + (\alpha_{TL_5} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_6}) \times (E_6 + (\alpha_{U_6} \times \Delta T_U) + (\alpha_{CU_6} \times \Delta T_{CU}) + (\alpha_{CL_6} \times \Delta T_{CL}) + (\alpha_{TL_6} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_7}) \times (E_7 + (\alpha_{U_7} \times \Delta T_U) + (\alpha_{CU_7} \times \Delta T_{CU}) + (\alpha_{CL_7} \times \Delta T_{CL}) + (\alpha_{TL_7} \times \Delta T_{TL}))) \\
 + & ((2 \times \alpha_{U_8}) \times (E_8 + (\alpha_{U_8} \times \Delta T_U) + (\alpha_{CU_8} \times \Delta T_{CU}) + (\alpha_{CL_8} \times \Delta T_{CL}) + (\alpha_{TL_8} \times \Delta T_{TL}))) \\
 - & 2 \times \left\{ (\alpha_{U_1}^2 + \alpha_{U_2}^2 + \alpha_{U_3}^2 + \alpha_{U_4}^2 + \alpha_{U_5}^2 + \alpha_{U_6}^2 + \alpha_{U_7}^2 + \alpha_{U_8}^2) \times \Delta T_U \right. \\
 + & ((\alpha_{U_1} \times \alpha_{CU_1}) + (\alpha_{U_2} \times \alpha_{CU_2}) + (\alpha_{U_3} \times \alpha_{CU_3}) + (\alpha_{U_4} \times \alpha_{CU_4}) \\
 & \quad + (\alpha_{U_5} \times \alpha_{CU_5}) + (\alpha_{U_6} \times \alpha_{CU_6}) + (\alpha_{U_7} \times \alpha_{CU_7}) + (\alpha_{U_8} \times \alpha_{CU_8})) \times \Delta T_{CU} \\
 + & ((\alpha_{U_1} \times \alpha_{CL_1}) + (\alpha_{U_2} \times \alpha_{CL_2}) + (\alpha_{U_3} \times \alpha_{CL_3}) + (\alpha_{U_4} \times \alpha_{CL_4}) \\
 & \quad + (\alpha_{U_5} \times \alpha_{CL_5}) + (\alpha_{U_6} \times \alpha_{CL_6}) + (\alpha_{U_7} \times \alpha_{CL_7}) + (\alpha_{U_8} \times \alpha_{CL_8})) \times \Delta T_{CL} \\
 + & ((\alpha_{U_1} \times \alpha_{TL_1}) + (\alpha_{U_2} \times \alpha_{TL_2}) + (\alpha_{U_3} \times \alpha_{TL_3}) + (\alpha_{U_4} \times \alpha_{TL_4}) \\
 & \quad + (\alpha_{U_5} \times \alpha_{TL_5}) + (\alpha_{U_6} \times \alpha_{TL_6}) + (\alpha_{U_7} \times \alpha_{TL_7}) + (\alpha_{U_8} \times \alpha_{TL_8})) \times \Delta T_{TL} \\
 + & \left. ((\alpha_{U_1} \times E_1) + (\alpha_{U_2} \times E_2) + (\alpha_{U_3} \times E_3) + (\alpha_{U_4} \times E_4) \right. \\
 & \quad \left. + (\alpha_{U_5} \times E_5) + (\alpha_{U_6} \times E_6) + (\alpha_{U_7} \times E_7) + (\alpha_{U_8} \times E_8) \right\} \quad \dots \dots (8)
 \end{aligned}$$

[0056] Like the above, if the partial differential of the valuation plan J is carried out about delta TCU, delta TCL, and delta TL, respectively, a degree type (9), (10), and (11) will be obtained.

[0057]

[Equation 6]

$$\frac{\partial J}{\partial \Delta T_{CU}} = 2 \times \{ ((\alpha_{U1} \times \alpha_{CU1}) + (\alpha_{U2} \times \alpha_{CU2}) + (\alpha_{U3} \times \alpha_{CU3}) + (\alpha_{U4} \times \alpha_{CU4}) \\ + (\alpha_{U5} \times \alpha_{CU5}) + (\alpha_{U6} \times \alpha_{CU6}) + (\alpha_{U7} \times \alpha_{CU7}) + (\alpha_{U8} \times \alpha_{CU8})) \times \Delta T_U \\ + (\alpha_{CU1}^2 + \alpha_{CU2}^2 + \alpha_{CU3}^2 + \alpha_{CU4}^2 + \alpha_{CU5}^2 + \alpha_{CU6}^2 + \alpha_{CU7}^2 + \alpha_{CU8}^2) \times \Delta T_{CU} \\ + ((\alpha_{CU1} \times \alpha_{CL1}) + (\alpha_{CU2} \times \alpha_{CL2}) + (\alpha_{CU3} \times \alpha_{CL3}) + (\alpha_{CU4} \times \alpha_{CL4}) \\ + (\alpha_{CU5} \times \alpha_{CL5}) + (\alpha_{CU6} \times \alpha_{CL6}) + (\alpha_{CU7} \times \alpha_{CL7}) + (\alpha_{CU8} \times \alpha_{CL8})) \times \Delta T_{CL} \\ + ((\alpha_{CU1} \times E_1) + (\alpha_{CU2} \times E_2) + (\alpha_{CU3} \times E_3) + (\alpha_{CU4} \times E_4) \\ + (\alpha_{CU5} \times E_5) + (\alpha_{CU6} \times E_6) + (\alpha_{CU7} \times E_7) + (\alpha_{CU8} \times E_8)) \} \\ \dots \dots \quad (9)$$

$$\frac{\partial J}{\partial \Delta T_{CL}} = 2 \times \{ ((\alpha_{U1} \times \alpha_{CL1}) + (\alpha_{U2} \times \alpha_{CL2}) + (\alpha_{U3} \times \alpha_{CL3}) + (\alpha_{U4} \times \alpha_{CL4}) \\ + (\alpha_{U5} \times \alpha_{CL5}) + (\alpha_{U6} \times \alpha_{CL6}) + (\alpha_{U7} \times \alpha_{CL7}) + (\alpha_{U8} \times \alpha_{CL8})) \times \Delta T_U \\ + ((\alpha_{CU1} \times \alpha_{CL1}) + (\alpha_{CU2} \times \alpha_{CL2}) + (\alpha_{CU3} \times \alpha_{CL3}) + (\alpha_{CU4} \times \alpha_{CL4}) \\ + (\alpha_{CU5} \times \alpha_{CL5}) + (\alpha_{CU6} \times \alpha_{CL6}) + (\alpha_{CU7} \times \alpha_{CL7}) + (\alpha_{CU8} \times \alpha_{CL8})) \times \Delta T_{CU} \\ + (\alpha_{CL1}^2 + \alpha_{CL2}^2 + \alpha_{CL3}^2 + \alpha_{CL4}^2 + \alpha_{CL5}^2 + \alpha_{CL6}^2 + \alpha_{CL7}^2 + \alpha_{CL8}^2) \times \Delta T_{CL} \\ + ((\alpha_{CL1} \times \alpha_{CL1}) + (\alpha_{CL2} \times \alpha_{CL2}) + (\alpha_{CL3} \times \alpha_{CL3}) + (\alpha_{CL4} \times \alpha_{CL4}) \\ + (\alpha_{CL5} \times \alpha_{CL5}) + (\alpha_{CL6} \times \alpha_{CL6}) + (\alpha_{CL7} \times \alpha_{CL7}) + (\alpha_{CL8} \times \alpha_{CL8})) \times \Delta T_L \\ + ((\alpha_{CL1} \times E_1) + (\alpha_{CL2} \times E_2) + (\alpha_{CL3} \times E_3) + (\alpha_{CL4} \times E_4) \\ + (\alpha_{CL5} \times E_5) + (\alpha_{CL6} \times E_6) + (\alpha_{CL7} \times E_7) + (\alpha_{CL8} \times E_8)) \} \\ \dots \dots \quad (10)$$

$$\frac{\partial J}{\partial \Delta T_L} = 2 \times \{ ((\alpha_{U1} \times \alpha_{L1}) + (\alpha_{U2} \times \alpha_{L2}) + (\alpha_{U3} \times \alpha_{L3}) + (\alpha_{U4} \times \alpha_{L4}) \\ + (\alpha_{U5} \times \alpha_{L5}) + (\alpha_{U6} \times \alpha_{L6}) + (\alpha_{U7} \times \alpha_{L7}) + (\alpha_{U8} \times \alpha_{L8})) \times \Delta T_U \\ + ((\alpha_{CU1} \times \alpha_{L1}) + (\alpha_{CU2} \times \alpha_{L2}) + (\alpha_{CU3} \times \alpha_{L3}) + (\alpha_{CU4} \times \alpha_{L4}) \\ + (\alpha_{CU5} \times \alpha_{L5}) + (\alpha_{CU6} \times \alpha_{L6}) + (\alpha_{CU7} \times \alpha_{L7}) + (\alpha_{CU8} \times \alpha_{L8})) \times \Delta T_{CU} \\ + ((\alpha_{CL1} \times \alpha_{L1}) + (\alpha_{CL2} \times \alpha_{L2}) + (\alpha_{CL3} \times \alpha_{L3}) + (\alpha_{CL4} \times \alpha_{L4}) \\ + (\alpha_{CL5} \times \alpha_{L5}) + (\alpha_{CL6} \times \alpha_{L6}) + (\alpha_{CL7} \times \alpha_{L7}) + (\alpha_{CL8} \times \alpha_{L8})) \times \Delta T_{CL} \\ + (\alpha_{L1}^2 + \alpha_{L2}^2 + \alpha_{L3}^2 + \alpha_{L4}^2 + \alpha_{L5}^2 + \alpha_{L6}^2 + \alpha_{L7}^2 + \alpha_{L8}^2) \times \Delta T_L \\ + ((\alpha_{L1} \times E_1) + (\alpha_{L2} \times E_2) + (\alpha_{L3} \times E_3) + (\alpha_{L4} \times E_4) \\ + (\alpha_{L5} \times E_5) + (\alpha_{L6} \times E_6) + (\alpha_{L7} \times E_7) + (\alpha_{L8} \times E_8)) \} \\ \dots \dots \quad (11)$$

[0058] Thus, it is based on the result of having carried out the partial differential of the valuation plan J about each elements delta TU, delta TCU, delta TCL, and delta TL of deltaT, and is [0059].

J/deltaTU=0**J/**deltaTCU=0**J/**deltaTCL=0**J/**deltaTL=0[0060] The equation carried out turns into 4 yuan the primary equation which makes a variable each elements delta TU, delta TCU, delta TCL, and delta TL of deltaC. The solution which solved these four equations as simultaneous equations, and delta TU, delta TCU, delta TCL and delta TL make a valuation plan J min, that is, are correction value of the target temperature over a cascade thermocouple which makes min the sum of the square of the error of the detection temperature of each wafer with a thermocouple, and target temperature.

[0061] Next, the solution method of the primary above-mentioned simultaneous equations of 4 yuan is shown. First, the formula set to **J/**deltaTU=0 can be expressed as a degree type (12).

[0062]

[Equation 7]

$$\begin{bmatrix} \alpha_{U1}^2 + \dots + \alpha_{U8}^2 \\ (\alpha_{U1} \times \alpha_{CU1}) + \dots + (\alpha_{U8} \times \alpha_{CU8}) \\ (\alpha_{U1} \times \alpha_{CL1}) + \dots + (\alpha_{U8} \times \alpha_{CL8}) \\ (\alpha_{U1} \times \alpha_{L1}) + \dots + (\alpha_{U8} \times \alpha_{L8}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} - (-1) \times ((\alpha_{U1} \times E_1) + \dots + (\alpha_{U8} \times E_8)) \\ \dots \dots \quad (12)$$

[0063] Similarly, the formula set to **J/**deltaTCU=0, **J/**deltaTCL=0, and **J/**deltaTL=0 can be expressed as a degree type (13), (14), and (15).

[0064]

[Equation 8]

$$\begin{bmatrix} (\alpha_{v1} \times \alpha_{cv1}) + \dots + (\alpha_{vs} \times \alpha_{cvs}) \\ \alpha_{cv1}^2 + \dots + \alpha_{cvs}^2 \\ (\alpha_{cv1} \times \alpha_{cl1}) + \dots + (\alpha_{cvs} \times \alpha_{cls}) \\ (\alpha_{cl1} \times \alpha_{ls}) + \dots + (\alpha_{cls} \times \alpha_{ls}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} = (-1) \times ((\alpha_{v1} \times E_1) + \dots + (\alpha_{vs} \times E_s)) \quad \dots \dots (13)$$

$$\begin{bmatrix} (\alpha_{v1} \times \alpha_{cl1}) + \dots + (\alpha_{vs} \times \alpha_{cls}) \\ \alpha_{cl1}^2 + \dots + \alpha_{cls}^2 \\ (\alpha_{cl1} \times \alpha_{ls}) + \dots + (\alpha_{cls} \times \alpha_{ls}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} = (-1) \times ((\alpha_{cl1} \times E_1) + \dots + (\alpha_{cls} \times E_s)) \quad \dots \dots (14)$$

$$\begin{bmatrix} (\alpha_{v1} \times \alpha_{ls}) + \dots + (\alpha_{vs} \times \alpha_{ls}) \\ \alpha_{ls}^2 + \dots + \alpha_{ls}^2 \\ (\alpha_{cl1} \times \alpha_{ls}) + \dots + (\alpha_{cls} \times \alpha_{ls}) \end{bmatrix}^T \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} = (-1) \times ((\alpha_{ls} \times E_1) + \dots + (\alpha_{ls} \times E_s)) \quad \dots \dots (15)$$

[0065] The four above-mentioned formulas can be expressed as (16) types using a matrix.

[0066]

[Equation 9]

$$\begin{bmatrix} \alpha_{v1}^2 + \dots + \alpha_{vs}^2 & (\alpha_{v1} \times \alpha_{cv1}) + \dots + (\alpha_{vs} \times \alpha_{cvs}) & (\alpha_{v1} \times \alpha_{cl1}) + \dots + (\alpha_{vs} \times \alpha_{cls}) & (\alpha_{v1} \times \alpha_{ls}) + \dots + (\alpha_{vs} \times \alpha_{ls}) \\ (\alpha_{v1} \times \alpha_{cv1}) + \dots + (\alpha_{vs} \times \alpha_{cvs}) & \alpha_{cv1}^2 + \dots + \alpha_{cvs}^2 & (\alpha_{cv1} \times \alpha_{cl1}) + \dots + (\alpha_{cvs} \times \alpha_{cls}) & (\alpha_{cv1} \times \alpha_{ls}) + \dots + (\alpha_{cvs} \times \alpha_{ls}) \\ (\alpha_{v1} \times \alpha_{cl1}) + \dots + (\alpha_{vs} \times \alpha_{cls}) & (\alpha_{cv1} \times \alpha_{cl1}) + \dots + (\alpha_{cvs} \times \alpha_{cls}) & \alpha_{cl1}^2 + \dots + \alpha_{cls}^2 & (\alpha_{cl1} \times \alpha_{ls}) + \dots + (\alpha_{cls} \times \alpha_{ls}) \\ (\alpha_{v1} \times \alpha_{ls}) + \dots + (\alpha_{vs} \times \alpha_{ls}) & (\alpha_{cv1} \times \alpha_{ls}) + \dots + (\alpha_{cvs} \times \alpha_{ls}) & (\alpha_{cl1} \times \alpha_{ls}) + \dots + (\alpha_{cls} \times \alpha_{ls}) & \alpha_{ls}^2 + \dots + \alpha_{ls}^2 \end{bmatrix} \times \begin{bmatrix} \Delta T_v \\ \Delta T_{cv} \\ \Delta T_{cl} \\ \Delta T_l \end{bmatrix} = \begin{bmatrix} (-1) \times ((\alpha_{v1} \times E_1) + \dots + (\alpha_{vs} \times E_s)) \\ (-1) \times ((\alpha_{cv1} \times E_1) + \dots + (\alpha_{cvs} \times E_s)) \\ (-1) \times ((\alpha_{cl1} \times E_1) + \dots + (\alpha_{cls} \times E_s)) \\ (-1) \times ((\alpha_{ls} \times E_1) + \dots + (\alpha_{ls} \times E_s)) \end{bmatrix} \quad \dots \dots (16)$$

[0067] In the above-mentioned formula (16), the matrix of the 1st term of left part can use the interference matrix M in a formula (2), and can express it as (17) types.

[0068]

[Equation 10]

$$\begin{bmatrix}
 \alpha_{U_1}^2 + \dots + \alpha_{U_8}^2 & (\alpha_{U_1} \times \alpha_{CU_1}) + \dots + (\alpha_{U_8} \times \alpha_{CU_8}) & (\alpha_{U_1} \times \alpha_{CL_1}) + \dots + (\alpha_{U_8} \times \alpha_{CL_8}) & (\alpha_{U_1} \times \alpha_{L_1}) + \dots + (\alpha_{U_8} \times \alpha_{L_8}) \\
 (\alpha_{U_1} \times \alpha_{CU_1}) + \dots + (\alpha_{U_8} \times \alpha_{CU_8}) & \alpha_{CU_1}^2 + \dots + \alpha_{CU_8}^2 & (\alpha_{CU_1} \times \alpha_{CL_1}) + \dots + (\alpha_{CU_8} \times \alpha_{CL_8}) & (\alpha_{CU_1} \times \alpha_{L_1}) + \dots + (\alpha_{CU_8} \times \alpha_{L_8}) \\
 (\alpha_{U_1} \times \alpha_{CL_1}) + \dots + (\alpha_{U_8} \times \alpha_{CL_8}) & (\alpha_{CL_1} \times \alpha_{CU_1}) + \dots + (\alpha_{CL_8} \times \alpha_{CU_8}) & \alpha_{CL_1}^2 + \dots + \alpha_{CL_8}^2 & (\alpha_{CL_1} \times \alpha_{L_1}) + \dots + (\alpha_{CL_8} \times \alpha_{L_8}) \\
 (\alpha_{U_1} \times \alpha_{L_1}) + \dots + (\alpha_{U_8} \times \alpha_{L_8}) & (\alpha_{CL_1} \times \alpha_{L_1}) + \dots + (\alpha_{CL_8} \times \alpha_{L_8}) & (\alpha_{L_1} \times \alpha_{CU_1}) + \dots + (\alpha_{L_8} \times \alpha_{CU_8}) & \alpha_{L_1}^2 + \dots + \alpha_{L_8}^2
 \end{bmatrix}$$

$$= \begin{bmatrix}
 \alpha_{U_1} & \alpha_{CU_1} & \alpha_{CL_1} & \alpha_{L_1} \\
 \alpha_{U_2} & \alpha_{CU_2} & \alpha_{CL_2} & \alpha_{L_2} \\
 \alpha_{U_3} & \alpha_{CU_3} & \alpha_{CL_3} & \alpha_{L_3} \\
 \alpha_{U_4} & \alpha_{CU_4} & \alpha_{CL_4} & \alpha_{L_4} \\
 \alpha_{U_5} & \alpha_{CU_5} & \alpha_{CL_5} & \alpha_{L_5} \\
 \alpha_{U_6} & \alpha_{CU_6} & \alpha_{CL_6} & \alpha_{L_6} \\
 \alpha_{U_7} & \alpha_{CU_7} & \alpha_{CL_7} & \alpha_{L_7} \\
 \alpha_{U_8} & \alpha_{CU_8} & \alpha_{CL_8} & \alpha_{L_8}
 \end{bmatrix}^T \times \begin{bmatrix}
 \alpha_{U_1} & \alpha_{CU_1} & \alpha_{CL_1} & \alpha_{L_1} \\
 \alpha_{U_2} & \alpha_{CU_2} & \alpha_{CL_2} & \alpha_{L_2} \\
 \alpha_{U_3} & \alpha_{CU_3} & \alpha_{CL_3} & \alpha_{L_3} \\
 \alpha_{U_4} & \alpha_{CU_4} & \alpha_{CL_4} & \alpha_{L_4} \\
 \alpha_{U_5} & \alpha_{CU_5} & \alpha_{CL_5} & \alpha_{L_5} \\
 \alpha_{U_6} & \alpha_{CU_6} & \alpha_{CL_6} & \alpha_{L_6} \\
 \alpha_{U_7} & \alpha_{CU_7} & \alpha_{CL_7} & \alpha_{L_7} \\
 \alpha_{U_8} & \alpha_{CU_8} & \alpha_{CL_8} & \alpha_{L_8}
 \end{bmatrix} = M^T \times M \quad \dots \dots (17)$$

[0069] Moreover, the column vector of the right-hand side can use the error P0 of the detection temperature of eight wafers with a thermocouple before the interference matrix M in a formula (2), and the adjustment in a formula (3), and target temperature, and can be expressed as (18) types.

[0070]

[Equation 11]

$$\begin{bmatrix}
 (-1) \times ((\alpha_{U_1} \times E_1) + \dots + (\alpha_{U_8} \times E_8)) \\
 (-1) \times ((\alpha_{CU_1} \times E_1) + \dots + (\alpha_{CU_8} \times E_8)) \\
 (-1) \times ((\alpha_{CL_1} \times E_1) + \dots + (\alpha_{CL_8} \times E_8)) \\
 (-1) \times ((\alpha_{L_1} \times E_1) + \dots + (\alpha_{L_8} \times E_8))
 \end{bmatrix}$$

$$= (-1) \times \begin{bmatrix}
 \alpha_{U_1} & \alpha_{CU_1} & \alpha_{CL_1} & \alpha_{L_1} \\
 \alpha_{U_2} & \alpha_{CU_2} & \alpha_{CL_2} & \alpha_{L_2} \\
 \alpha_{U_3} & \alpha_{CU_3} & \alpha_{CL_3} & \alpha_{L_3} \\
 \alpha_{U_4} & \alpha_{CU_4} & \alpha_{CL_4} & \alpha_{L_4} \\
 \alpha_{U_5} & \alpha_{CU_5} & \alpha_{CL_5} & \alpha_{L_5} \\
 \alpha_{U_6} & \alpha_{CU_6} & \alpha_{CL_6} & \alpha_{L_6} \\
 \alpha_{U_7} & \alpha_{CU_7} & \alpha_{CL_7} & \alpha_{L_7} \\
 \alpha_{U_8} & \alpha_{CU_8} & \alpha_{CL_8} & \alpha_{L_8}
 \end{bmatrix} \times \begin{bmatrix}
 E_1 \\
 E_2 \\
 E_3 \\
 E_4 \\
 E_5 \\
 E_6 \\
 E_7 \\
 E_8
 \end{bmatrix}$$

$$= (-1) \times M^T \times P_0 \quad \dots \dots (18)$$

[0071] Therefore, it can express (19) equations and the simultaneous equations of an equation (16) are [0072].

[Equation 12]

$$[M^T \times M] \times \begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} = (-1) \times M^T \times P_0 \quad \dots \dots (19)$$

[0073] It will become (20) types if inverse-matrix [MTxM]-1 is hung from Hidari of both sides.

[0074]

[Equation 13]

$$\begin{bmatrix} \Delta T_U \\ \Delta T_{CU} \\ \Delta T_{CL} \\ \Delta T_L \end{bmatrix} = [M^T \times M]^{-1} \times (-1) \times M^T \times P_0 \quad \dots \dots (20)$$

[0075] Since M and P0 in the right-hand side of a formula (20) are the numeric value already acquired as an error of the detection temperature of eight wafers with a thermocouple before an interference matrix and

adjustment, and target temperature, delta TU, delta TCU, delta TCL, and delta TL are calculated by assigning the value to a formula (20).

[0076] Thus, it is the correction value of the target temperature over the cascade thermocouple for making into min the valuation plan J aiming at delta TU, delta TCU, delta TCL, and delta TL which were computed making the result significant work which can guarantee the quality more than fixed level as a product increase.

Although how to solve the simultaneous equations created by the partial differential was explained in order in order to calculate each element of deltaC which makes a valuation plan J min, and delta TU, delta TCU, delta TCL and delta TL in an above-mentioned example By not solving simultaneous equations, acquiring the error P0 of the detection temperature of eight wafers with a thermocouple before the interference matrix M and adjustment, and target temperature, and assigning the value to an actual activity at the above-mentioned equation (20) The correction value of the target temperature over a cascade thermocouple can be calculated. At the end, it controls using the calculated correction value, and the result of adjustment is checked.

[0077] In the configuration shown in drawing 1 and drawing 2 , the correction value computed above, respectively, and delta TU, delta TCU, delta TCL and delta TL are added to the target temperature over the cascade thermocouple of each heating zone (U, CU, CL, L zone). And it controls so that this target temperature and the detection temperature of a cascade thermocouple are in agreement. Time amount fully passes and the error of the detection temperature of eight wafers with a thermocouple and original target temperature is checked in the place by which temperature was stabilized. Adjustment will be ended if each error is in tolerance. An addition is adjusted when the error has exceeded tolerance. Although the procedure of additional adjustment is the same as the above-mentioned case that time -- the 1st adjustment -- the error of the detection temperature of eight wafers with a thermocouple before adjustment, and target temperature -- acquiring -- P0 -- carrying out -- **** (formula (3)) -- in additional adjustment The error of the detection temperature of eight wafers with a thermocouple in the check of the 1st adjustment result and original target temperature is acquired, respectively, and it is used as P0. Like the above, the rest is substituted for a formula (20), calculates delta TU, delta TCU, delta TCL, and delta TL, and adds them to the target temperature over the cascade thermocouple of each heating zone which amended this delta TU, delta TCU, delta TCL, and delta TL by the 1st adjustment further. And it controls so that this target temperature and the detection temperature of a cascade thermocouple are in agreement, and the result of readjustment is checked. Usually, although a good result can be obtained by 1 - 2 times, and less than at most three adjustments, when still exceeding tolerance, rerunning from acquisition of an interference matrix is desirable.

[0078] The temperature control approach and thermal treatment equipment which were explained above are used as the semi-conductor manufacture approach in semiconductor fabrication machines and equipment. For example, there is the following about the diffusion process at the time of being applied to dispersion equipment.

** Pie ROJIE nick hydrogen oxide gas is burned with oxygen gas, generate a steam, introduce the steam into a reaction chamber, and oxidize the film deposited on the wafer or the wafer. Processing temperature is 700-1000 degrees C, and a pressure is processed by ordinary pressure. When an oxidation rate is taken into consideration, as suitable processing temperature, it is 800-1000 degrees C.

** Introduce dry oxidation oxygen gas in a reaction chamber, and oxidize the film deposited on the wafer or the wafer. Processing temperature is processed by ordinary pressure at 700-1000 degrees C. When an oxidation rate is taken into consideration, as suitable processing temperature, it is 800-1000 degrees C.

** Introduce in a reaction chamber by making phosphorus diffusion phosphorus trichloride (POCl₃), oxygen gas, and nitrogen gas into carrier gas. Processing temperature is processed by ordinary pressure at 800-1000 degrees C.

** Inert gas, such as annealing treatment nitrogen gas, is introduced in a reaction chamber, processing temperature is processed at 800-1100 degrees C, and a pressure is processed by ordinary pressure.

[0079] In a semiconductor device, above-mentioned process ** and ** are widely used for the mask of the insulating separation between components, an electrode or the separation between layers of wiring, the gate oxide of MOSFET, the memory cell accumulation-of-electricity part by volume of DRAM, impurity diffusion, and an ion implantation, surface passivation, protection, etc. Moreover, it is used for doping to a gate electrode and the polish recon film of wiring, a resistor, doping to the contact section, etc. in above-mentioned process **. Moreover, it is used for moving the impurity to an impurity layer to the interior of a crystal in above-mentioned

process **.

[0080] Although the gestalt 1 of gestalt 2. implementation of operation explained the case where correction value was calculated before a real process, you may make it calculate direct correction value into a real process. By searching for the interference matrix M before a real process, acquiring the error P0 of the detection temperature of eight wafers with a thermocouple, and target temperature during the substrate processing which is a real process, and substituting for a formula (20), the gestalt 2 of operation can calculate the correction value of the target temperature over a cascade thermocouple, and can apply and carry out temperature control of this calculated correction value to target temperature.

[0081] With the gestalt 2 of gestalt 3. implementation of operation, in a wafer with a thermocouple, since a thermocouple will be exposed during substrate processing, there is a possibility that metal contamination may arise. Then, it changes to a wafer with a thermocouple and you may make it insert a profile thermocouple into a furnace. Since the profile thermocouple 200 has the structure which has covered the thermocouple with the ceramic tubes 201, such as a quartz tube or SiC, as shown in drawing 3, it can reduce the metal contamination by the thermocouple 204. In a ceramic tube 201, the thermocouple 204 of plurality (8) is enclosed by the thermocouple enclosure section 202, and the temperature detecting signal is obtained through wiring 203. Each thermocouple is formed in the location (height location) corresponding to each wafer with a thermocouple shown in the gestalt 1 of operation. This profile thermocouple consists of single tubing, and is suitable for inserting into the reaction chamber where space is comparatively narrow. In addition, temperature detection in much locations is also attained more by preparing two or more these further.

[0082] When detecting the error of detection temperature and target temperature in gestalt 4. of operation, and a real process, as a heater thermocouple (thermocouple for heater control) 300 as shown in drawing 4 The correction value of target temperature is calculated, and this calculated correction value is applied to target temperature, and may be made to carry out temperature control by forming eight cascade thermocouples 304, acquiring the difference of the detection temperature and target temperature of this cascade thermocouple as an error P0, and substituting for a formula (20). In addition, the thermocouple 300 for heater control shown in drawing 4 installs the quartz with which the cascade thermocouple 304 was enclosed, or eight ceramic tubes 301 of SiC side by side in the thermocouple enclosure section 305, incurvates this between a liner tube (12 of drawing 1 R>1), and a coil (13 of drawing 1), and enables it to insert them. Since such a cascade thermocouple 304 is separately enclosed with the ceramic tube 301, it can prevent interference between cascade thermocouple 304. In addition, when there is no fear of such interference, you may make it insert two or more thermocouples in one ceramic tube.

[0083] Each gestalt of the operation which explained more than gestalt 5. of operation has the long substrate processing time, and even if it carries out some temperature rise and fall at the time of searching for an interference matrix, when heat-treating the semiconductor device which trouble does not produce, an interference matrix asks during the substrate processing which is a real process, and target temperature may make amend in quest of an error and correction value further, although the interference matrix M searches for before a real process.

[0084] Although the gestalt of the operation described more than gestalt 6. of operation explained the vertical mold equipment with which a heating zone is divided into a lengthwise direction, the wafer from one sheet to several sheets is processed, and this invention can be applied also to the sheet equipment with which a heating zone is divided into wafer side inboard. It is the top view in which drawing 5 shows this sheet equipment, (a) shows a side elevation and (b) shows two or more zones. In this case, if it changes to the temperature detection by the wafer with a thermocouple and a radiation thermometer is used, it can measure by non-contact, and it becomes easy to prevent metal contamination. The susceptor 4 which lays a wafer (substrate 2) in the heating furnace 1 which has coil 1a which is a processing room being formed, and heating the inside of a heating furnace 1 to predetermined temperature, it supplies reactant gas and the sheet equipment shown in drawing 5 forms a thin film on a substrate 2. The heater 3 which is a source of heating has three zones of **, **, and ** as a heating zone, and the heat from each zone is absorbed by the reactant gas which flows from the susceptor 4 which supports the substrate 2 which mainly has heat capacity, a substrate 2, and a gas pipe 5.

[0085] As a sensor for control, it is used for each heating zone (******) of every as two radiation thermometers (infrared ray radiation thermometer: the 2nd thermometric element) 6A-6F and the object for heater monitors, or an object for heater control, and the heater thermocouples 7A-7C corresponding to the cascade thermometer

of vertical mold equipment are formed. In the temperature-controller AD translation section 8, the AD translation of the thermocouple signal is carried out, and temperature digital data is transmitted to the temperature-controller control section 9. Similarly, radiation thermometers 6A-6F also carry out the AD translation of the sensor signal, and transmit temperature digital data to the temperature-controller control section 9. Using the received temperature digital data, the temperature-controller control section 9 performs control operations (PID etc.), and determines a heater power value (0 - 100%). The target temperature used in this PID control has composition amended by correction value as stated above. In addition, the thyristor controller 410 heats a heater for the electrical signal (0 - 100%) from the thermoregulator control section 9 by reception and thyristor ignition. In addition, while the Main controller 412 is connected through AC power supply 411, the thermoregulator display control unit 413 is connected to the thermoregulator control section 9. Moreover, AC power supply 414 is connected to the radiation thermometer 6 and the thermoregulator control section 9.

[0086] The radiation thermometers 6A-6F in the gestalt of this operation are installed in coil 1a, in order to measure correctly the temperature of the susceptor 4 as a device under test and to control the temperature of a susceptor 4. It can be measured by non-contact that a radiation thermometer is used as a temperature sensor, and it is because responsibility is good. Moreover, it is because it becomes impossible to attach this thermocouple in a susceptor from that measurement principle, therefore to rotate a susceptor 4 in this case when a radiation thermometer is used as a thermocouple. Thus, as for sheet equipment, the number of the heater thermocouple (the 1st thermometric element) with which vertical mold equipment and the number of zones differ and correspond, and radiation thermometers (the 2nd thermometric element) is also changed suitably. Also in such sheet equipment, the temperature homogeneity to the field inboard of a wafer can be raised by applying this invention. In addition, in the wafer with a thermocouple explained in vertical mold equipment, it is also possible by forming two or more thermocouples in the same wafer side further to raise the temperature homogeneity to field inboard also in vertical mold equipment.

[0087] In the above, although the gestalt of operation of the temperature control approach in the field of a processed object by this invention was explained, even if it is not the operator who became skillful by performing these procedures, soak adjustment in the field of a processed object can be ensured early. Moreover, automatic soak adjustment in the field of a processed object which does not need a break in of a skillful operator can be performed by programming the above procedure by computer and including in a temperature controller etc. as software. For example, a setup of the target temperature over the cascade thermocouple which brings about a result as shown by drawing 9 by above-mentioned computerization becomes possible automatically. In addition, in the above-mentioned example, although eight wafers with a thermocouple were used, a larger field can also be adjusted to a uniform temperature requirement in a finer unit by using the same means using a thermocouple with the approach of using much more wafers with a thermocouple, and the device which moves the side of a topmost part wafer to a bottom wafer up and down. Moreover, although the above example explained the case where a cascade thermocouple was used for control, in the case of the structure where a cascade thermocouple cannot always be installed, a heater thermocouple can be used instead, and it can also adjust to it similarly. Moreover, it is also possible to use a radiation thermometer instead of a wafer with a thermocouple.

[0088]

[Effect of the Invention] As explained above, even if according to this invention it is possible to set up automatically the amended target temperature over two or more fields which actually perform temperature control using a computer and there is not a skilled operator, the optimal heat treatment for a short time and accuracy can be performed.

[Translation done.]

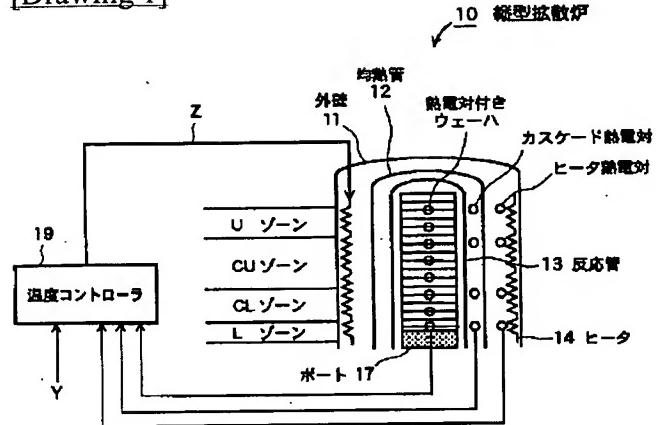
* NOTICES *

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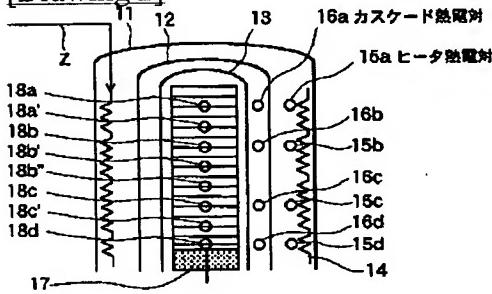
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DRAWINGS

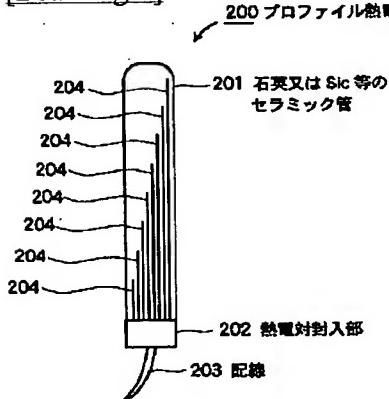
[Drawing 1]



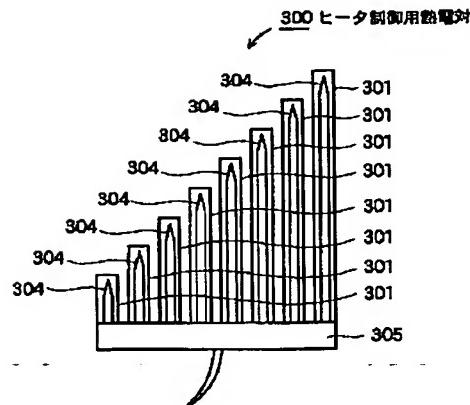
[Drawing 2]



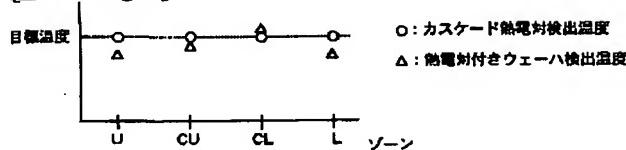
[Drawing 3]



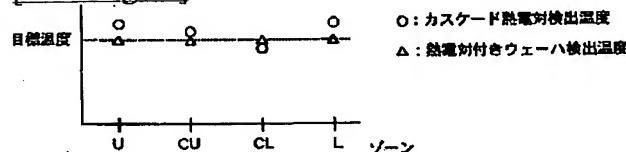
[Drawing 4]



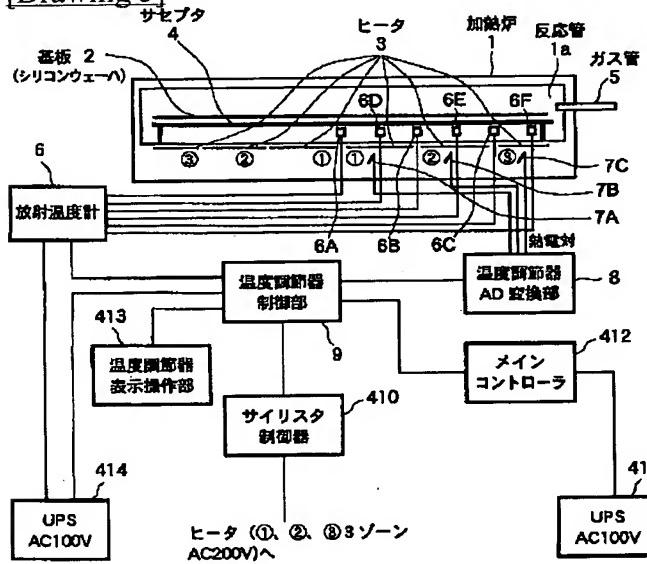
[Drawing 9]



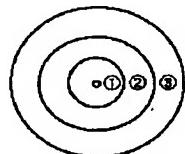
[Drawing 10]



[Drawing 5]

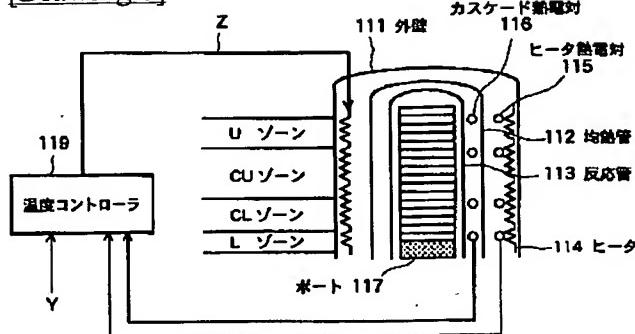


(b)

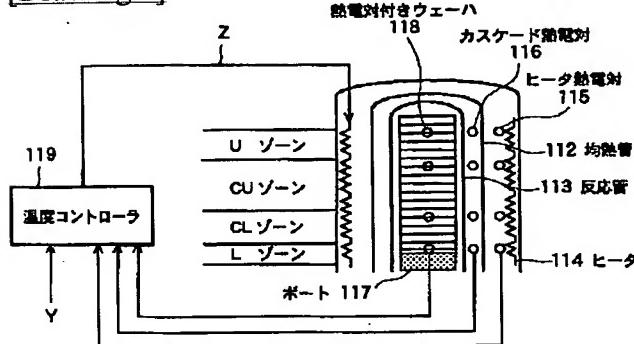


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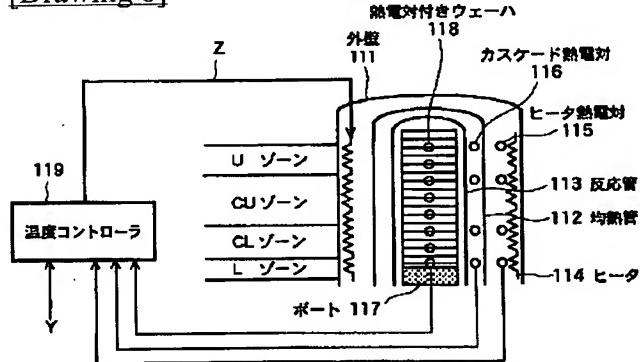
[Drawing 6]



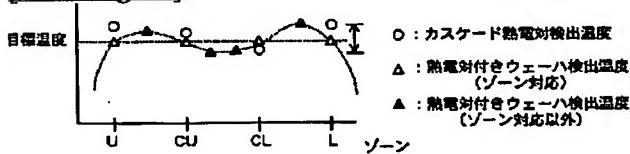
[Drawing 7]



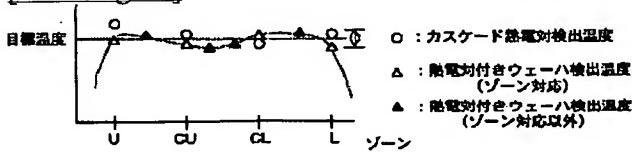
[Drawing 8]



[Drawing 11]



[Drawing 12]



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CORRECTION OR AMENDMENT

[Kind of official gazette] Correction of a open patent official report

[Section partition] The 3rd partition of the 6th section

[Publication date] October 4, Heisei 14 (2002. 10.4)

[Publication No.] Provisional publication of a patent 2002-175123 (P2002-175123A)

[Date of Publication] June 21, Heisei 14 (2002. 6.21)

[Annual volume number] Open patent official report 14-1752

[Application number] Application for patent 2001-272218 (P2001-272218)

[Correction summary] It corrects per classification incorrect ** as follows.

[Account]

[The 7th edition of International Patent Classification]

[**]

G05D 23/19 G

H01L 21/22 501 N

511 Q

21/324 T

[Forward]

G05D 23/22 A

H01L 21/22 501 N

511 Q

21/324 T

[Translation done.]